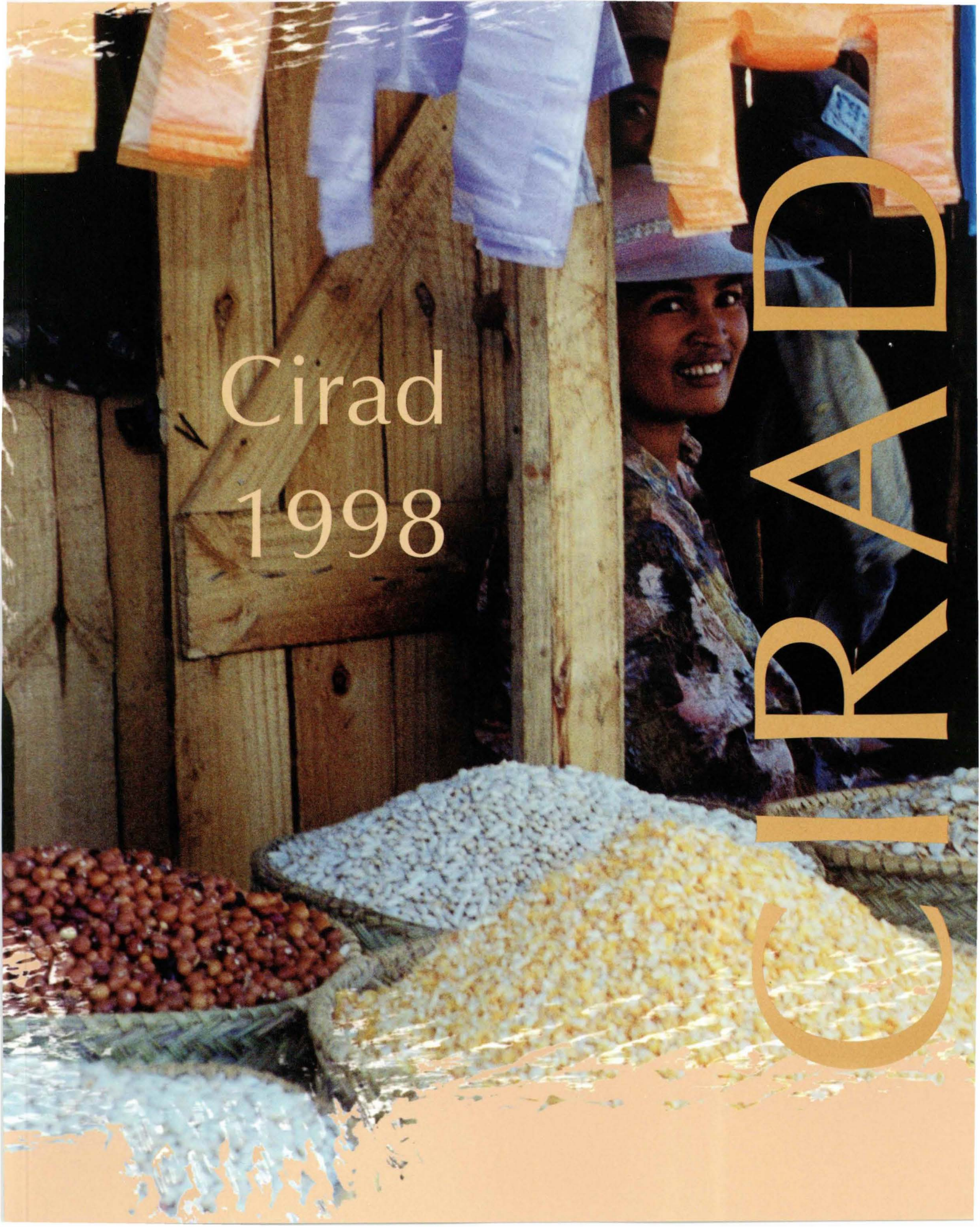
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CIRAD

CIRAD 1998

The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French scientific organization specializing in agricultural research for development for the tropics and subtropics. It is a state-owned body, which was established in 1984 following the consolidation of French agricultural, veterinary, forestry, and food technology research organizations for the tropics and subtropics.

CIRAD's mission is to contribute to the economic development of these regions through research, experiments, training, and dissemination of scientific and technical information.

The Centre employs 1800 persons, including 900 senior staff, who work in more than 50 countries. Its budget amounts to approximately French francs 1 billion (€152 million), more than half of which is derived from public funds.

CIRAD is organized into seven departments: CIRAD-CA (annual crops), CIRAD-CP (tree crops), CIRAD-FLHOR (fruit and horticultural crops), CIRAD-EMVT (animal production and veterinary medicine), CIRAD-Forêt (forestry), CIRAD-TERA (territories, environment, and people), and CIRAD-AMIS (advanced methods for innovation in science). CIRAD operates through its own research centres, national agricultural research systems, or development projects.

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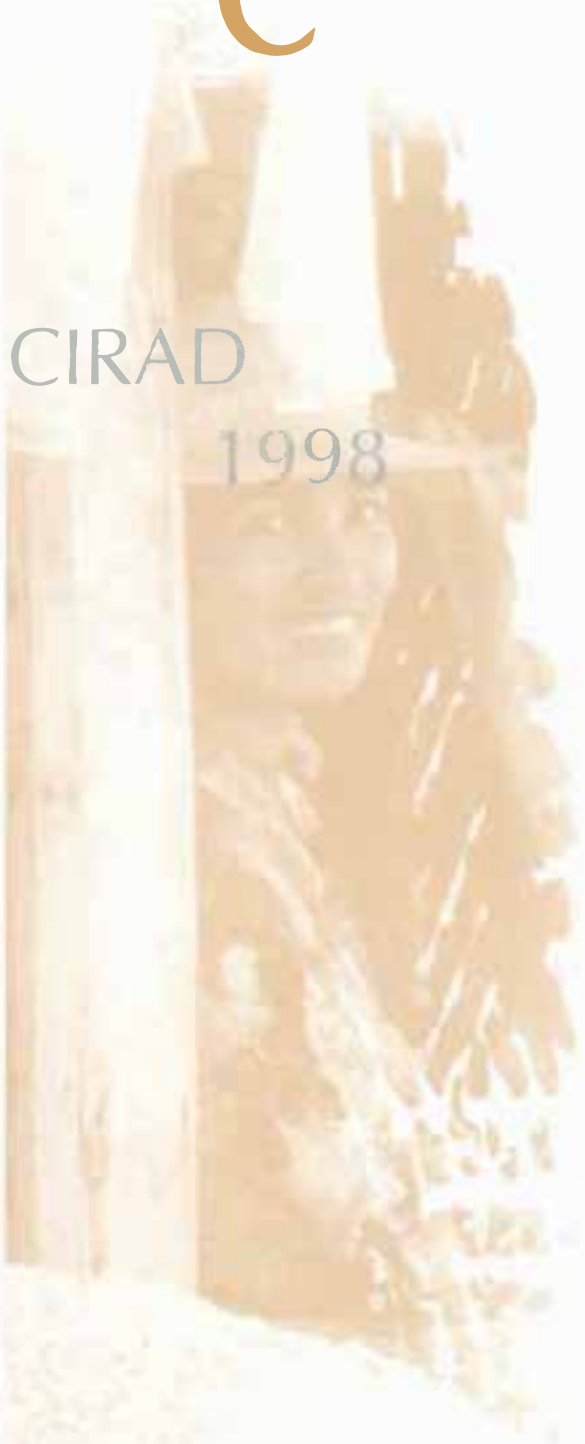

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Message from the President

In 1998, CIRAD focused on forging and formalizing alliances with research organizations, universities, and businesses in both the South and North. It has thus succeeded in creating new links between different but complementary structures. Through these alliances CIRAD will be able to diversify its interventions and broaden its scope of action in its incessant effort to enhance the quality of its research.

We see decisive change in the nature of scientific collaboration between Southern and Northern research organizations. For many years, North–South cooperation was based primarily on the secondment of Northern researchers to institutions in the South. National authorities of these countries have now indicated to CIRAD that although such joint projects are indispensable, they would like their own researchers to acquire knowledge by working in modern laboratories in the North. CIRAD's participation in the creation of an international platform for advanced research in Montpellier is in line with this thinking. The platform will mobilize, in joint research projects, advanced research organizations and universities from France, national research organizations of the South, centres of the Consultative Group on International Agricultural Research, and private enterprises.

Direct alliances between CIRAD and Southern organizations are also entering a new phase. Let me give three examples. CIRAD's collaboration with CNRST, the national centre for scientific and technological research of Burkina Faso, involves not only research and training but also capacity building. This partnership aims to strengthen the two organizations so that they continue to fulfil their mandates more effectively. An agreement was signed with the Chinese Academy of Sciences, and a joint project on plant modelling and architecture was launched. CIRAD strengthened its ties with Indonesia; together with the Indonesian ministries, it participates in the Agribusiness project, which supplies small businesses in five agricultural regions with the agroclimatic data they require for their rainfed crops.

Agribusiness and food industries contribute significantly to socioeconomic development in the South and to its integration in the world economy. CIRAD has also signed agreements with companies in these sectors. Two projects launched with private enterprises in 1998 deserve to be mentioned. The first, called Génoplante, aims to decode the entire rice genome and to determine the functions of the identified genes. For this project, CIRAD works with Rhône-Poulenc, Biogemma, seed companies, and the French research organizations INRA, CNRS, and IRD. Génoplante demonstrates how advanced research initially oriented towards developing countries can also contribute significantly towards improved competitiveness of Northern agriculture. CIRAD's involvement guarantees scientific progress on a vital staple crop of the tropics and ensures that the countries of the region have access to new knowledge generated through the project. The second project, Prosper, concerns a very different field. In this project, research organizations, and agribusiness and food companies—primarily small and medium-sized enterprises—work together to set up R&D projects

and to promote technology transfer to tropical regions. CIRAD brings to the companies its technical know-how and field experience. Various operations have already been launched in Brazil, Morocco, and Thailand.

New alliances were also forged in France. CIRAD collaborates with French universities and agricultural colleges to create platforms for hosting and training students and researchers from the South. Students thus have an opportunity to work on topics related to tropical agriculture, while researchers can build on their past experience and knowledge. CIRAD has created a structure for coordinating international research training networks. It will prepare individualized programmes for visiting researchers, mobilize CIRAD's teams for training activities, and participate in scientific exchange networks.

In March 1998, as part of a long-standing partnership, CIRAD and INRA signed a letter of intent for strengthening collaboration between the two organizations. Both agree to work together in a way that allows them to fulfil their respective research and cooperation missions effectively. Accordingly, joint laboratories and projects have been established, and a common approach has been adopted for other countries (China, Brazil, South Africa) and regions (Caribbean).

As I complete seven years as President of CIRAD's Board of Trustees, it is heartening for me to witness the emergence of these new alliances, which bring together public and private organizations, from the North and the South, and from research and education. All concur that agricultural research for development will be a key issue of the twenty-first century. New means will be used to address this issue. But the spirit of cooperation and solidarity will remain unchanged.

Guy Paillotin
President
CIRAD Board of Trustees

adapting to a new research environment

CIRAD redefines its partnership strategy

The national and international research scenario is changing radically. Scientific institutions, driven by the globalization of economies, advance of technology, and ever increasing competition are joining forces and forging new alliances. CIRAD, together with its partners in agricultural research for development, plays an active role in this movement.

In 1998, major initiatives were undertaken aimed at organizing research for generation of knowledge and its transfer and application. Influenced by the combined effects of globalization, technological progress, and scientific competition, these initiatives, irrespective of their origin or scale, share a common objective. They all aim to create centres of excellence based on three key principles: stronger links between research and training, collaboration between public and private research bodies, and organization of international cooperation.

For the research community in the South, the changes sometimes appear to represent more a risk of exclusion and growing inequality than an opportunity. CIRAD believes, on the contrary, that the changes will bring new opportunities for cooperation to scientists working in research for development. For this reason, CIRAD is deeply committed to the construction and coordination of these new forms of partnership.

organizing international cooperation

The forces that are shaping the world economy are also structuring research. Information and communication technologies have accelerated scientific exchange across the globe. Competition and relocation have concentrated resources and skills within centres of excellence, which are themselves interlinked in an increasingly tight network. If this process continues unchecked, it will inevitably marginalize the poorest countries, the very countries that need research most. Mainstream international organizations, despite their undeniable sectoral achievements, will not be able to cover these needs.

Tropical agricultural research needs support. Scientific institutions working in this field strive to do this through their efforts to build a global agricultural research system.

The national agricultural research systems form the cornerstone of this system; they bring together all the stakeholders in each country: research institutes, universities, the private sector, farmers' organizations, NGOs, and others. The priority is to strengthen these systems and facilitate their participation in the regional and subregional systems of research partnerships focused on long-term common objectives. These national and regional systems will interact with all stakeholders in agricultural research for development, including advanced research organizations and universities in the North, international agricultural research centres, and others.

To this end, the Electronic Global Forum for Agricultural Research (EGFAR) is developing a global information and communication system supported by the InfoSys system of the European Initiative for Agricultural Research for Development (EIARD).

The international community, working in a spirit of cooperation and solidarity, must respond to the challenges facing mankind at the dawn of the twenty-first century. It must find ways to increase food security on the planet, to promote sustainable management of natural resources, and to reduce poverty. With this in mind, the national and regional committees of the global forum have laid down three research priorities.

For the first priority—genetic resource management and biotechnology—the concept of international research platforms is gaining ground. The idea is to create facilities for hosting researchers from the South in the large advanced biotechnology research organizations specializing in tropical crops. Platforms of this type are being set up at Agropolis in Montpellier, France, and at Cornell University in the United States.

For the second priority—natural resource management and agroecology—research will be based in the tropical regions. Regional committees play a key role in the creation and coordination of centres of excellence for research on regional development. PRASAC, a regional research centre for the central African savannah, offers a good example of such centres, where local stakeholders in agriculture and development are supported by national institutes, advanced research organizations from the North, and the international centres.

The third priority—competitiveness of local agriculture and product quality—also calls for a streamlining of cooperation. Accordingly, organizations specializing in certain major crops like

banana and cocoa are coordinating and combining their activities. Similar international programmes are also planned for staple crops.

associating research and training

"Research serves education, education serves the civil society." Guided by this mission, the French Ministry of Higher Education and Research launched a series of reforms to ensure a more efficient transfer of innovations from research organizations for the benefit of national development. In its long-term strategy for the "university of the third millennium", the Ministry advocates the creation of mixed research units that involve both research organizations and establishments of higher education (universities, technology institutes). These changes are a step towards a radical restructuring of research and scientific education into centres of excellence to create a coherent knowledge system. An important element of the system is increased cooperation with European and North American systems.

The reforms will facilitate CIRAD's efforts to strengthen its ties with advanced research teams. They also offer two significant opportunities for its research for development.

CIRAD can now stimulate the interest of academic institutions in the problems facing developing countries and encourage them to integrate certain issues of global importance into their programme. CIRAD can also now involve students and researchers from the South, and thus fulfil its mandate of training both for research and through research.

CIRAD is actively involved in negotiating contractual agreements for joint research programmes with universities and agricultural colleges. Several projects are being finalized: with the research organizations IRD, CNRS, and INRA, and the Universities of Montpellier and Perpignan for rice genetics; with the agricultural college ENSAM and the University of Montpellier for genetic resources and for genome management, improvement, and protection of Mediterranean and tropical crops; with INRA, IRD, and ENSAM for tropical and Mediterranean symbioses; with the engineering college ENGREF, INRA, and the University of Guiana for a forestry project based in Kourou .

Other forms of collaboration were initiated in 1998 with a view to strengthening the existing and planned centres of research, mainly on animal genetics and livestock production, process engineering and food sciences, resource management and sciences related to territory management.

In one such initiative, researchers from the University of Paris I, a nongovernmental organization, and research organizations work together on the campus of the Jardin Tropical outside Paris. The aim is to establish an international reference centre for development economics and poverty reduction studies. The mission of the centre is to promote sustainable development through research and training. The central theme is divided into its two components: development (analysis of economic and social change, impact of globalization, nontradable goods and services, public policies) and sustainability (models that incorporate environmental aspects, stakeholders' strategies, and development policies). The centre also hosts visiting researchers from the South.

These links with universities and education institutions must be supported by initiatives for hosting and training researchers from the South, so that they can also benefit from the new synergies. To this end, the Office of the Research Director at CIRAD has created a structure for coordinating international research training networks.

CIRAD has been managing, since several years, a budget allocated by the French government to finance short visits by researchers from countries with which France has long-standing cooperation links. In 1999, the Ministry of Foreign Affairs

renewed the budget and widened its geographic scope. CIRAD supplements this amount with a matching grant from its own budget, which was reserved until now for countries outside its traditional sphere of cooperation. To simplify administrative procedures, the two budget lines will be combined into one and CIRAD will issue two calls for proposals targeting all countries without restriction. Its objective is to strengthen and widen its partnership networks. Priority is given to cost-effective initiatives that offer the best possibility of supporting this objective. In-service training is an effective option; CIRAD can invite up to 60 researchers each year for a total period of around 90 months. For Brazil, Senegal, and Thailand, for example, these training programmes aim to combine knowledge transfer and networking with partner university institutions.

These programmes are coordinated by the new structure for international research training networks. Currently, its resources are used mainly to cover the matching grant. However, more substantial, long-term funding needs to be identified for the future.

developing the French overseas departments and territories

Negotiations for the contracts between the French government and its constituent regions also provide an opportunity to define a nationwide research strategy for the next five years. The development issues and research priorities concerning the French overseas departments and territories (DOM-TOMs) are significant for CIRAD. The DOM-TOMs are situated in the tropics where agriculture, the main occupation, is confronted with specific socioeconomic problems. Dependence on food imports, poor export crop production, soil erosion and degradation, population growth, and rural migration place increasing pressure on resources. Environmental protection and sustainability are key issues.

CIRAD assumes a special responsibility for these regions, where research conducted over decades on crops such as banana and sugarcane and on livestock production is now supplemented by more systems-oriented programmes. The new approach supports smallholder farming based on a variety of crops, often combined with livestock production. For commercial plantations, the approach is based on crop diversification through crop rotation, so that the enterprise meets the dual objectives of disease-free output and environment conservation. These developments also offer CIRAD the opportunity to adapt and implement its cooperation strategy.

CIRAD contributes to the emergence of competitive regional centres for research and training. It achieves this by bridging research laboratories and development actions; by creating joint research units with INRA, IRD, and universities; and by opening its laboratories to scientists from the North and South. The creation of the forest research laboratory in Kourou, French Guiana, strengthens ongoing research in French Guiana and Brazil on conservation of natural forests, value addition for forest products, and stabilization of pioneer fronts.

In the Caribbean, CIRAD and INRA have joined forces to support agricultural development in Guadeloupe and Martinique and to extend regional cooperation. They have decided to launch research projects on sustainable cropping systems and economic viability of farms, in association with the University of Antilles-Guyane and professional partners. A centre for agricultural research is being created in Martinique and another for biotechnology is planned for Guadeloupe.

Following an analysis of crop protection requirements, a centre of excellence devoted to plant pathology was created in Réunion. Here, CIRAD will work with the University of Réunion, the local plant protection department, and federation of pest control groups. CIRAD's team will focus on the epidemiology of tropical diseases (particularly bacterial diseases), dynamics of insect pest populations,

virus disease transmission mechanisms, and plant resistance to pests and diseases. The high-quality research and training facilities and the efforts of the institutional partners will make this centre of excellence a reference for the entire Indian ocean region and beyond.

Other specialized centres of excellence are under consideration, including one on food processing in Réunion and another in New Caledonia on either local agrifood systems or biodiversity management and environmental protection. Thanks to the commitment of CIRAD and the local authorities, these centres of excellence in the DOM-TOMs will become important nodes of international cooperation networks.

cooperating with the private sector

Globalization of trade, liberalization of national economies, and concomitant devolution of governments all lead to a diversification of stakeholders. In the countries of the South, private companies and professional organizations play an increasingly significant role in both research and development. Their contribution to economic and social development is now recognized by governments and international organizations, and often the participation of one or more companies is a prerequisite for public project financing.

In keeping with this trend, CIRAD endeavours to increase its links with the private sector in the South. It seeks partnerships from a wide range of target groups: cooperatives and farmers' organizations, small and medium-sized food processing and agricultural services companies, large-scale plantation and food businesses, and multinational corporations investing in backward integration.

In some cases, collaboration with large companies is the only means to ensure that innovations reach the developing countries. This is the case for biotechnology, a sector in which private companies have made massive investments in knowledge-based tools and methods. Use of this knowledge by developing countries will depend on the possibility of accessing privately-owned techniques. They need to develop, either by themselves or with the help of partners, the applications that are no longer pursued by multinational groups. Public research organizations in industrialized countries can serve as intermediaries to enable developing countries pursue their research through cooperation in fields of strategic importance for their future.

CIRAD has thus volunteered to take part in the Génoplante project, which involves both public and private partners in an ambitious genomics programme on two model plants, thale cress for dicotyledons and rice for monocotyledons. For nearly 20 years now, CIRAD and IRD have worked with organizations in the South and the International Rice Research Institute (IRRI) on numerous projects focusing on the assessment and analysis of *Oryza* germplasm, development of new rice varieties and corresponding cultivation methods, and development of genetic transformation methods for resistance to viruses, insects, drought, and salinity. CIRAD and IRD intend to maintain their position as leaders in research on rice, the staple food of half the world's population. The challenge is to safeguard access to fundamental knowledge concerning the rice genome and to establish a portfolio of patents and genes that can be used directly or through exchange to enhance rice production. This knowledge will also be used to improve other tropical cereals, such as sorghum, maize, and sugarcane, to ultimately benefit development in the South.

In developing countries, annual crops are grown mainly to meet the subsistence requirements of farming families. Smallholders should therefore be given the means to increase output of their food crops. Surplus produce of cereals, pulses, roots, and tubers can represent a source of income for farmers, who have started selling it on urban markets and to food processing companies. They therefore have to meet the same quality standards expected from industrial crops such as cotton and sugarcane.

CIRAD-CA, the Annual Crops Department, develops plant varieties and agricultural techniques that are suited to farmers' strategies and market requirements. These components are integrated into cropping systems that are designed to optimize natural resources and all the production factors on farms. In a context of diverse and rapidly changing agricultural situations, the acquisition of information, references, and scientific knowledge becomes a continual exercise. In-depth knowledge is needed on plant species and their natural enemies, the impact of cropping systems on the environment, and factors that determine product quality. It serves to determine the prospects of technical innovations, to anticipate their impact, and to adapt them rapidly to new situations.

Research partnerships form an important element of the Department's strategy. It participates actively in the work of specialized international bodies such as the International Cotton Advisory Committee (ICAC) and the International Society of Sugar Cane Technologists (ISSCT). The Department also collaborates with the centres of the Consultative Group on International Agricultural Research (CGIAR). The collaboration with the International Rice Research Institute (IRRI) on rainfed rice has been extended to irrigated rice, and CIRAD's research station in Vietnam has been selected as a reference site for IRRI's ecoregional initiative. The West Africa Rice Development Association (WARDA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) are long-standing partners for projects in Africa. The regional centres of the conference of African agricultural research coordinators CORAF, particularly PRASAC for savannah research in central Africa, are focal points for the Department's cooperative work in central and western Africa.

The private sector is increasingly involved in commodity sectors such as groundnut, cotton, and sugarcane following government devolution and privatization. The Department works with national research centres and French companies to support efforts to enhance production, to design decision support systems, and to develop human resources.

Annual Crops

sugarcane

progress in controlling two important diseases

Considerable research has been undertaken on two sugarcane diseases: leaf scald due to the bacterium *Xanthomonas albilineans* and sugarcane yellow leaf syndrome due to a luteovirus (ScYLV).

Recent occurrence of leaf scald in Guadeloupe led to a new finding on the epidemiology of the disease: healthy micropropagated sugarcane plantlets can be contaminated in the field by airborne bacteria. Several months after field planting, *X. albilineans* was detected in dewdrops on plant leaves. Leaf scald symptoms appeared a few weeks later, and an analysis of the isolates confirmed that the pathogen had infiltrated into some stalks. This indicates that, although the disease is transmitted mainly through cuttings or during harvesting, other factors should be taken into account for epidemiological studies and control strategies.

Studies conducted in Montpellier, Guadeloupe, and Réunion also confirmed that behaviour of sugarcane plants after *X. albilineans* infection should not be solely evaluated on the basis of expressed symptoms. Stalks of certain test cultivars considered resistant because they did not exhibit disease symptoms were found to be heavily colonized by the pathogen. High densities of bacteria in the stalks could have a serious impact on plant growth and yields. Resistance of sugarcane stalks to bacterial colonization is a new criterion for assessing disease resistance. In Guadeloupe, plant stalks were inoculated with *X. albilineans*, and pathogen population densities were measured. The tests led to the identification of potential parents belonging to several wild *Saccharum* species, mainly *S. spontaneum*, which can resist colonization and symptom development.

Two new tests for detecting the sugarcane yellow leaf virus were developed in collaboration with the University of Minnesota and the United States Sugar Corporation (US Sugar) and are now being used by CIRAD. The first, an RT-PCR (reverse transcription–polymerase chain reaction) molecular test, amplifies specific nucleotide sequences of the virus. The second is a serological test in which specific antibodies are used to detect the virus in leaf midrib imprints on nitrocellulose membranes.

The two tests were used to analyze 2400 specimens collected in Réunion from the three main commercially-grown sugarcane varieties in seven different sugarcane-growing areas. Virus contamination was observed in all three varieties and across the survey areas. It was also detected in Guadeloupe in more than 40% of the test varieties in variety performance trials. However, in Guadeloupe and Réunion, leaf yellowing was not always caused by the virus. Other biotic or abiotic factors are probably involved in symptom development. The luteovirus was also detected in several sugarcane cultivars monitored at CIRAD's international quarantine facilities in Montpellier, France.

Prolonged hot water treatment of cuttings did not kill the virus in infected sugarcane stalks. In-vitro culture, on the other hand, was found to be effective for sanitizing ScYLV-infected sugarcane: of 404 micropropagatedplantlets, almost 90% of those derived from meristem cultures and 30% of those from bud cultures were virus-free. CIRAD's quarantine

service plans to use this technique for supplying certified disease-free sugarcane varieties.

constraints to cropping on vertisols

Vertisols cover more than 300 million ha of the earth's surface. They occur mainly in tropical and subtropical regions with a seasonally dry period. These dark soils with high clay content are the most fertile soils of the semiarid zones and therefore of significant importance for agriculture in these areas. But they are difficult to cultivate because they become sticky and pasty when wet and hard with large cracks when dry.

In Guadeloupe, most sugarcane crops are grown on vertisols. CIRAD studied soil porosity of these vertisols. The two types of porosity are: matrix porosity formed by spaces between clay plates and structural porosity formed by larger spaces created mainly by biological activity. Only water contained in the structural pores is readily available to plants. The shape and volume of this effective porosity was visualized by infiltrating fluorescent resin into the soil. Soil behaviour, particularly the detrimental effects of compaction by heavy farm machinery, can be understood by examining the architecture (tubes, channels, cracks) of dry and wet soils before and after tillage.

Current sugarcane yields on vertisols in Guadeloupe are below the yield potential based on agroclimatic parameters. CIRAD's studies show that nitrogen absorption and yields decline as the number of ratoons increases. Nitrogen occurs in the structural pores and is absorbed by plants through the soil solution. Its uptake decreases when soil compaction due to successive regrowths reduces porosity. Declining sugarcane yields are thus attributed to nitrogen deficiency in plants linked to the physical properties of the soil. Nitrogen supply from urea applications is reduced considerably because of losses due to volatilization of urea; soil reserves are therefore the main source of nitrogen supply to sugarcane plants. For ratoon crops, it is therefore important to maintain the structural properties of vertisols and to adopt an irrigation technique that not only satisfies crop water requirements but also activates nitrogen mineralization in the soil.

In Sudan, the Kenana Sugar Company manages 35 000 ha of completely mechanized sugarcane plantations on vertisols with furrow irrigation. But after 15 years of cultivation, yields started to decline. CIRAD was commissioned to conduct studies on the physical and chemical status of the soil and on irrigation and fertilizer application. Nitrogen supply to ratoons was not found to be a limiting factor as in Guadeloupe. Urea was sidedressed and incorporated in the soil so that it was available in the surface layers. Irrigating crops with fresh water from the Nile reduced soil salinity but it could also eventually break down the soil structure by increasing soil alkalinity. A marked reduction in soil porosity was observed between plant rows, which increased bulk density, especially around fine aggregates. As the compacted area was deeper than the tilled area, plant roots could not penetrate beyond the tilled zone to the water and mineral resources. This explains why sugarcane yields rapidly decline over successive ratoon crops.

Recommendations proposed on the basis of the studies concerned mainly soil tillage techniques. The aim was to maintain soil porosity of the vertisols and thus increase nutrient and water supply to plants. In Guadeloupe, the technique recommended was deep-tillage chisel ploughing in the interrows of the harvested crop, followed by planting of the new crop in the tilled interrow. It is a simple technique, which is as effective as standard tillage and two discing operations. Chemical destruction of stubble was also recommended to preserve soil porosity created by the root systems of the harvested crop. Decompacting the soil in the interrows by harrowing would also enhance water and mineral supply. In Sudan, direct replanting on the previous crop was recommended because the soils are still porous.

cotton

a cotton research tool: COTONS

COTONS is a model that simulates the growth and development of cotton. It was developed by CIRADwithin the framework of a Science and Technology for Development (STD) project of the European Union; a team from the United States Department of Agriculture (USDA) also participated in the project. COTONS is unique in that it combines mechanistic modelling of the physiological processes and three-dimensional display of plant architecture. The model is also innovative as it can simulate plant variability in a cotton field due to competition.

COTONS draws on the American GOSSYM model, but offers additional enhanced features. Its simulations of light interception also account for competition between plants within a stand. Modelling of basic processes such as emergence, growth, and abscission has also been considerably improved. Carbohydrate supply and demand for the plant are simulated for each day of the cropping cycle, based on environmental conditions and stand status. Carbohydrate supply deficit relative to potential demand from different plant organs is represented in terms of stress levels. Varying degrees of water, nitrogen, and carbon stresses are applied to the different organs to show resulting reduction in growth or abscission of fruiting organs. Carbohydrate distribution priorities vary during a plant's growth cycle; for example, plant growth is halted when photosynthetic energy is entirely channelled to the developing cotton bolls. COTONS offers two modes of simulation: in the "average plant" mode, the crop field is represented by an average plant; the "stand" mode integrates competition between plants and display of different plant architectures within the crop cover. The input variables required for simulating the behaviour of a cotton field cover parameters related to climate (rainfall, solar radiation, temperature), soil characteristics (texture, carbon and nitrogen availability, moisture contents at different soil water potentials), and cropping techniques (varieties, sowing dates and densities, fertilizer application, irrigation, and growth regulators).

COTONS is a useful tool for designing experiments and interpreting results in all cotton research disciplines. It can be used by geneticists to assess the adaptation potential of a variety to specific environmental conditions, or to characterize the abscission susceptibility and photosynthetic potential of a genotype. Entomologists can use it to evaluate host plant reaction to pest infestation of leaves or during boll formation. The model also determines infestation thresholds for launching cost-effective control operations. COTONS helps agronomists analyze factors that reduce yields (mineral and water supply, plant density), test crop management sequences prior to field experiments, and predict yields under given climatic conditions. The graphic displays of plant growth make COTONS a useful tool for training extension staff. Private companies involved in cotton production and consulting services will find COTONS a very useful tool for developing specific recommendations on the basis of environmental constraints and yield targets, and for customizing technical advice and predicting yields.

a new cotton variety for Brazil

Since the beginning of the 1990s, especially after Brazil adopted legislation for protection of plant varieties, the country's

cotton seed market has grown rapidly. Competition has increased with the entry of public and private, national and multinational companies in the domestic seed industry.

It is in this competitive context that the new cotton variety CD 401 is being marketed in three southern Brazilian states—Paraná, São Paulo, and Mato Grosso do Sul. It is the result of CIRAD's collaboration since 1990 with COODETEC, an association of cooperatives in the state of Paraná. The cotton research programme conducted with CIRAD's collaboration and initially limited to Paraná was subsequently extended and adapted to the fundamental changes in cotton cultivation in Brazil. There has been a sharp reduction in low-input small-scale cotton cultivation as smallholders are not in a position to implement the increasingly complex technical recommendations. The trend towards completely mechanized cultivation is gaining ground. The cotton-growing area is also shifting from the traditional regions in the southern states to central-western Brazil, mainly in the *cerrados*, which offer considerable potential for mechanization and more favourable climatic conditions.

CD 401 is a high-yielding, early variety with good fertilizer response. It has high tolerance to fungal diseases occurring in southern Brazil, but it is susceptible to nematodes. This variety is suited to both manual and mechanical harvesting and gives high ginning yields. Its excellent fibre quality makes it one of the best varieties among the medium-length fibre varieties currently grown in Brazil. Local manufacturers also appreciate the strength, fineness, and maturity of its fibre. CD 401 has considerably enhanced the reputation of Brazilian cotton. CIRAD's contract with COODETEC allows it to share the commercial benefits from CD 401's success, which is also due to efficient seed multiplication and dynamic marketing through COODETEC's distribution network.

The Brazilian programme conducted in a context marked by the specificity and variability of crop situations offered an interesting opportunity for innovative and original research on mechanization and genotype × cropping system interactions, as well as the genetic factors that control tolerance to a diverse complex of fungal, bacterial, and viral diseases. The ultimate aim of the programme is to offer farmers a sufficiently wide range of competitive varieties that match the diverse cropping conditions found in Brazil.

After eight years of fruitful collaboration between CIRAD and COODETEC, a new phase of joint actions is planned. They will focus on genetic transformation of cotton, through the use of advanced biotechnologies on a broad genetic base obtained previously through standard plant breeding methods. The main goal will be to improve pest resistance in cotton varieties by inserting *Bacillus thuringiensis* genes.

the second World Cotton Research Conference

In September 1998, the second World Cotton Research Conference was held in Athens, Greece. It was organized by the International Cotton Advisory Committee (ICAC) and attended by 650 representatives of research and development organizations and private companies from more than 50 countries. More than 300 papers were presented, providing an up-to-date overview of all areas of cotton research. CIRAD provided financial support and coordinated several technical sessions. Its cotton research activities were presented through 18 papers and an exhibit stand. Participants expressed keen interest in CIRAD's work on the COTONS model, rational pest and disease management in French-speaking Africa, and fibre contaminants. The success of the conference confirmed the importance of such international events, particularly for cotton, which is not a mandate crop of any international agricultural research centre. CIRAD's 50-year experience in cooperative research with many cotton-growing countries places it in a position to take a leading role in the creation of a world cotton research programme.

quality of traditional porridge in southern Africa

As part of a European Union collaborative project, consumer preferences concerning sorghum and millet products were studied in southern Africa from 1994 to 1998. The African partners in the project were the Agricultural University of Sokoine, Tanzania, and the Botswana Technology Centre (BTC); the European partners were the Natural Resources Institute (NRI), United Kingdom; the tropical research institute IICT, Portugal; and CIRAD. Surveys were carried out in Tanzania and Botswana to determine consumer preferences and demand for sorghum and millet, to identify local or newly introduced varieties that were preferred by consumers, and to develop new food products that could compete with the wheat and maize products manufactured in urban centres. The ultimate objective is to revive interest in sorghum and millet, which have been marginalized by maize in most countries of the region. The rationale is that sorhgum and millet are better adapted to the prolonged dry spells common to the region.

Thick porridges called *bogobe* in Botswana and *ugali* in Tanzania are the preferred traditional foods. CIRAD's cereal technology laboratory developed two tests to assess the suitability of grains of different sorghum and millet varieties for making thick porridges according to consumers' requirements. The first step was to identify the main porridge quality criteria used by consumers and to determine traditional preparation techniques and test them in the laboratory with small quantities of grain samples. A test to assess porridge quality was developed and the physicochemical aspects of quality were analyzed. The findings led to the development of a porridge quality scale and the identification of varieties producing the type of grain quality sought by consumers. Among the preferred sorghum varieties were the local Segaolane, Langa-langa, and Mbangala, as well as the recent introductions Phofu, Pato, Larsvyt, Kuyuma, and those being developed by ICRISAT in Zimbabwe.

The two tests were then compared with one previously developed by CIRAD for assessing *tô,* a thick porridge that is popular in western Africa. It was found that sorghum varieties that are suitable for making *tô* in western Africa are also suitable for making *ugali* and *bogobe* in southern Africa. Preferred varieties can therefore be interchanged between southern and western Africa, provided they adapt to local agroclimatic conditions.

The physicochemical analysis showed that porridge consistency was determined by the starch content of grain and flour produced from it. Grain with a high starch content thus produces firm and thick porridge. For smooth porridges such as *ugali* that are prepared with less flour, seed coat components (bran and germ) with high mineral, lipid, and protein contents reduce porridge thickness. High starch content and good dehulling properties are the grain qualities required for obtaining or appropriate consistency for *ugali.* Grainy textured porridges such as *bogobe* are made with large quantities of flour; therefore the presence of nonflour components does not affect cohesiveness of the paste or modify its texture. High starch content is the only factor governing *bogobe* porridge quality.

The results explain the success of the sorghum flours sold in supermarkets in Botswana, which are

produced by around 70 flour mills. Although these products are not of the same quality as traditional flours, they are generally appreciated for their convenience (ready-to-cook), reasonable price, and overall quality. The presence of bran and germ in the flour, which cannot be avoided in industrial processing, does not appear to affect consumer acceptance.

agrosystems

high-yielding and sustainable maize cropping systems in Mexico

Maize production in Mexico is exposed to severe international competition following the signing of the North American Free Trade Agreement (NAFTA) and the major agricultural policy changes—new land-use regulations—by the Mexican government in the 1990s. The immediate need is to rapidly increase output, but without jeopardizing long-term production potential. Since 1994, a team of CIRAD agronomists and economists has been working with the International Maize and Wheat Improvement Center (CIMMYT) and the Mexican forestry and agriculture research institute INIFAP in a project aimed at the development of cropping techniques that will ensure higher, sustained maize yields and conserve soil fertility. The technique being studied is direct sowing on straw mulch as a means to enhance water use efficiency. The project is conducted in a small region in the state of Jalisco at an altitude of about 1000 m; the climate is characterized by irregular rainfall (400–800 mm/year). Trials in other locations are conducted through the INIFAP's country-wide network.

The mechanisms that control water and mineral flow under mulch cover were studied at plot level, and their effect on maize yield was assessed. The medium-term cumulative effects of mulching on soil fertility and biological activity were monitored in permanent test plots. A sample of representative farms was also monitored monthly for analyzing farmers' practices. Based on these

recurrent selection of rice: a regional network in Latin America

The rice improvement programme in Latin America and the West Indies is jointly conducted by CIRAD and the International Center for Tropical Agriculture (CIAT). The originality of the programme is the use of recurrent selection for a self-pollinated species. Base populations were first established in Brazil, in partnership with the Brazilian agricultural research centre EMBRAPA and other national agricultural research centres in Latin America. The programme used a male sterile gene isolated by IRRI. Since 1992, new rice varieties created at CIAT have been disseminated to other partners in Latin America. At each site, the populations evolve under selection pressure and with the incorporation of new genetic variability that meets the specific requirements of each country in terms of grain type, organoleptic qualities, and resistance to major constraints. In this way the breeding method creates new variability by accumulating traits for local adaptation.

In addition, training sessions on recurrent selection procedures were organized and a technical manual was published.

At present, 10 Latin American countries (Argentina, Bolivia, Chile, Colombia, Costa Rica, Cuba, El Salvador, Panama, Uruguay, and Venezuela) operate recurrent selection programmes, using the new populations. Brazil operates its own breeding programme since 1985, in collaboration with CIRAD.

support to French companies for effluent management

Stricter environmental regulations, particularly for effluent management, are compelling greater compliance by all stakeholders including individuals, farmers, and agrifood and other industries. CIRAD is working with three French companies to develop innovative solutions to address this need.

Studies were conducted with a private-sector company in Brittany, France, to control pollution from pig production units. They led to the development of Agrifiltre, a process for treating animal waste, which complies with legal stipulations for nitrogen and phosphorus fertilizers. In a related development, new regulations in France for agricultural use of urban sluge impose prior treatment of wastes before application in the fields. CIRAD assists a private sector company in the Languedoc-Roussillon region in southern France in adapting the Agrifiltre process for sluge treatment. The project receives financial support from ANVAR, the French research promotion agency.

A French multinational food group has retained CIRAD as consultant for a project on agricultural use of effluents. Fertigation is a low-cost technique for processing effluents, which could be suitable for tropical regions to meet the high demand for water and fertilizer for agricultural production. An experimental site was established in southern United States to test this technique, and feasibility studies are under way in Argentina and Australia.

analyses, an economic model was developed to identify and assess obstacles to the adoption of the proposed techniques. Subsequently, the regional potential of the technique will be assessed by means of an agricultural model combined with a geographic information system (GIS).

Results demonstrate the efficiency of direct sowing on mulch. Yields increased substantially owing to a 30-percent improvement in rainwater storage compared with existing cultivation techniques. But the lack of special seed drills and difficulties in weeding operations limit widespread adoption of this technique. The studies have also been useful for developing new modules for biophysical models to assess the beneficial effects of mulch cover.

In another study undertaken in Mexico and Brazil, economic and biophysical models were combined to study maize yield variability factors, particularly preliminary cultivation techniques. Yield variability was expressed as variability in gross margins at plot level or variability in annual income at farm level. The study was useful for understanding the reasons for adoption or nonadoption of the direct sowing on mulch technique.

A simple water balance model was also adapted to assess the effects of crop residue mulch. A general soil and climate database was used for applying the model across locations in Jalisco. The data were spatialized through a GIS system to display rainfall use efficiency depending on the type of preliminary cultivation techniques, so that appropriate recommendations can be proposed to improve water management and yields.

Following the success of the first phase of the project, plans for the second phase are under way. The research will focus on the diversification of systems based on direct sowing on mulch for enhancing biomass use: intercropping and rotations with legume crops, use of cover crops where climatic conditions are favourable, and improvement of forage systems during the dry season. The new components should improve adaptation of these systems to local soil and climate conditions and farmers' socioeconomic situations. The involvement of farmers in participatory research projects for developing new cropping systems should facilitate dissemination of these techniques to the commercial crop sector. The second phase will also extend collaborative activities by involving the Mexican development sector. The operation also offers the opportunity to bring together international networks for sustainable agriculture based on direct seeding on mulch. CIMMYT's networks in Latin America, southern Africa, and the Ganges plain will thus work together with those of CIRAD in Brazil, Central America, and the Indian ocean region.

CIRAD-CP, the Tree Crops Department, established its research plan for 1998–2002, following the external review held in 1997. The research will continue to be organized according to commodities—cocoa, coconut, coffee, oil palm, and rubber. For the work programme, the Department identified the constraints and potential of the different stakeholders involved in the commodity sectors for defining the research requirements and priorities.

The commodity-based research structure must also take account of the integration of crops into the overall farming systems. Once developed, technical innovations must be transferred. The Department's commodity-based research will therefore be combined with studies that cover the farm and its environment.

The globalization and liberalization of markets in recent years has introduced new scenarios in the different crop sectors. An objective approach is needed to understand the constraints facing producers, most of them smallholders working in rural areas.

To address these issues, the Department will systematically integrate social sciences into its well-established thematic research. For this, it will strengthen its own expertise and work with other CIRAD programmes.

The Department places particular emphasis on maintaining its strong position in the field. It plans to increase the strength of its researchers in producer countries and to concentrate its long-term activities in a few key countries. It is also increasingly involved in international networks such as COGENT, INGENIC, and RECA. The Department closely monitors changes in the international agricultural research system to identify new opportunities for tree crops.

Tree Crops

cocoa

revival of fine cocoas in Ecuador

The cocoa of Ecuador has acquired a reputation for the distinctive arriba flavour of its traditional Nacional type cacao trees grown along the watercourses flowing into the Pacific. Its quality has deteriorated recently for two reasons: the spread of the more productive Trinitario hybrids (although they take longer to ferment and do not produce the arriba flavour) and a marketing system that fails to provide any incentive to produce quality cocoa.

In recent years, the Ecuadorian Ministry of Agriculture has sought to promote the production of fine cocoa, with support from exporters and producers' associations. Since 1995, CIRAD has been working together with the Ecuadorian national agricultural research institute, INIAP, and the German consultancy firm, ARCOTRASS, on a project funded by Ecuador, France, and the European Union. The project aims to encourage the production of quality cocoa by ensuring its offtake through a marketing system formed by associations. It has organized small- and medium-scale producers into legally established associations that buy superior quality cocoa from producers and sell it to exporters. The share of the profits passed back to producers allows them to improve their living conditions. The project also covers the construction of postharvest processing facilities (fermenters, drying areas, warehouses) and supplies equipment and credit for marketing operations. Eight associations have already started marketing several dozen tonnes of cocoa, at a 15–20% premium over the usual price. The associations distribute part of the profits to the producers and reinvest the rest to ensure continuity of the business.

The ambitious aim of the project is to organize direct exports of arriba cocoa by setting up a company that groups all the associations and collects the cocoa produced by members. With a regular supply of larger volumes of quality cocoa, the company should be able to find more profitable markets, primarily in Europe.

The project also trains producers and supervisory staff in the adoption of new crop management sequences, farm management, organization of associations, and other relevant aspects.

For the research component of the project, a novel participatory method based on tasting of fresh beans was developed for selection. In this way, trees that produce high quality beans can be identified in old cacao plantings. Sixty-eight cultivars were identified and budded onto clone IMC 67, which is resistant to *Ceratocystis* wilt. Their main phenological characteristics will be evaluated at INIAP's Pichilingue experimental station.

somatic embryogenesis of cocoa

Trees with desirable traits are multiplied by vegetative propagation (based on cuttings or budding) for distribution to planters. Somatic embryogenesis offers a reliable solution for mass or large-scale multiplication.

For cocoa, the technique is still at the research stage. Exchanges between the University of Pennsylvania, USA, and CIRAD have resulted in considerable improvements to the technique developed jointly by CIRAD and Nestlé. Several in-vitro plantlets were obtained for around ten clones from staminodes (floral organs) used as

explants. However, high variability was observed mainly in the embryogenic capacity of the test genotypes, the number of somatic embryos per embryogenic staminode, and the number of normal embryos capable of producing plantlets.

Further improvements are needed in certain stages of the process to make the technique commercially viable. In the embryogenic capacity maintenance phase, in particular, the main problem is tissue oxidation. Ongoing research on the soluble sugar and organic acid contents of seed albumen during embryo growth will provide references for developing appropriate culture media. The research also focuses on macroelements such as potassium, magnesium, sulphates, and phosphates. The culture system based on temporary immersion developed in parallel by CIRAD also significantly improves somatic embryo growth.

coffee

improving farming systems

Technical frames of reference are developed by CIRAD through its participatory research networks with producers, and it is enhancing its research and development operations for this purpose. The aim is to identify crop management sequences that are not only quantitatively and qualitatively effective, but also economically adapted to different production conditions and, above all, to the preservation of coffee ecosystems.

In Laos, for instance, the area under coffee on the Bolovens plateau has doubled since 1993, sometimes to the detriment of subsistence crops. To ensure that this rapid development of coffee cultivation is well managed, CIRAD is participating in a project for the overall development of the plateau. The project is partly funded by AFD, the French development agency, and coordinated by BDPA, the French agency for developing agricultural production; it is undertaken on behalf of the Laotian Ministry

prospects for the cocoa industry

During the past few years, economic liberalization and globalization have led to increased world trade in cocoa, a change in the relationship between government authorities and processing companies, the emergence of new stakeholders, and expansion of the area under cacao.

What are the prospects for cocoa between now and 2010? In an attempt to find the answer, CIRAD's cocoa strategic planning group put forward three scenarios. In the first scenario, the current trend will continue: the majority of producers will still be smallholders, natural resources in producer countries will deteriorate, and processing companies will be faced with supply shortages. The second scenario is more optimistic; it predicts sustainable development of the sector to the benefit of all concerned: adoption of sedentary, intensive cropping practices by planters, emergence of producers' organizations and private enterprises, and increase in cocoa demand and chocolate consumption. The third scenario is pessimistic and predicts a production crisis: heavy parasite pressure, labour shortages, fall in output, and reduction of cocoa content in chocolate products and its substitution by vegetable fats, texturizers, and artificial flavourings.

CIRAD has based its research priorities for cocoa on this study. It will focus on sustainable cocoa-based farming systems in Africa, integrated control of Phytophthora *pod rots, revival of the production of fine cocoas in South America, and analysis of the quality chain from cultivation to processing.*

support for the Cameroonian quality observatory

As African countries gradually liberalize marketing of agricultural commodities, the responsibility for quality control is increasingly delegated to private companies. The Cameroonian quality observatory, which was set up in response to this situation, is recognized as the official body for export checks of both coffee and cocoa.
CIRAD provides technical assistance to the observatory for the services provided to the different operators in the sector. At its facilities in Douala, the observatory issues inspection certificates after checking product conformity according to standard technical procedures. It carries out checks at upstream product purchasing points, bulk warehouses, and processing plants. Additional analyses are carried out on export batches to check conformity to importers' specifications of fat and free fatty acid contents for cocoa and cup quality for coffee.
The observatory inspected 75% of the cocoa exported by Cameroon during 1998/99 and conducted additional analyses for 31 000 t of cocoa. Quality control is thus supported by quality guarantees for a part of the exports.

of Agriculture. The two objectives pursued by CIRAD are: to increase productivity so as to curb the trend towards coffee monocropping and land saturation, and to improve the quality of the Bolovens plateau coffee, which is valued at 10–15% below the average price on the world market.

A study of the commodity chain revealed that smallholders' income was relatively high in relation to world coffee prices; however, plantation productivity could be improved. Experimental and demonstration plots on smallholdings have gradually encouraged planters to adopt plantation upkeep and rejuvenation, intercropping, and new techniques such as drying beans on racks.

In the *jardin créole* coffee plantations of Haiti, the incidence of soil parasites and tree felling to make charcoal have created a mosaic of completely shady and entirely exposed areas, and of densely planted plots and patches with no coffee trees. The deteriorating state of plantations and intraplot variability hinder the adoption of standard crop management sequences, which would probably have exactly the opposite effect in many plots.

The coffee plantation rehabilitation programme funded by the European Union supports planters' associations with the objectives of enhancing coffee production and marketing quality products. The programme follows a three-pronged strategy: demonstrate the use of plot diagnosis to members of coffee planters' associations so that they can select the appropriate options, depending on financial resources and labour availability; train producers in the different techniques to be adopted in line with the diagnosis and selected options; and strengthen the associations that supply the seedlings and inputs required for rehabilitating the plantations.

genetic modification of coffee

Leaf miners *Leucoptera* and *Perileucoptera* are the main coffee pests in Brazil and eastern Africa. It is sometimes difficult to control these pests without using environmentally-hazardous insecticides.

CIRAD has been working with Nestlé since 1994 on the genetic modification of coffee. Genes of the *Bacillus thuringiensis* bacterium that code the toxins against the coffee leaf miner were found to be effective against *Perileucoptera coffeella*. Nestlé and CIRAD developed a technique for genetically modifying somatic embryos of coffee; it is based on the use of bacteria of the genus *Agrobacterium*, which naturally transfer part of their DNA to the plants they infect. Some 200 plants were obtained by independent integration of DNA. After a molecular analysis, the genetically modified plants were tested for their effective resistance to the pests.

The next step is to transfer the plants to the field and test their agronomic conformity, technological quality, and resistance

to the target pests under natural conditions. The trial involving 50 clones produced by independent modifications of a *Coffea canephora* genotype has received the approval of the French biomolecular engineering commission. It will be conducted in French Guiana. Pollen transfer and the impact of transgenes on local insect populations will also be studied during the trial.

coconut

coconut ecophysiology applied to development

In a research operation funded by the European Union, the Department and CIRAD's plant modelling laboratory developed a coconut leaf architecture model for producing three-dimensional computer mock-ups. The mock-ups simulate radiation interception in coconut plantations under different conditions and can estimate the residual radiation available to intercrops in the understorey.

Other research organizations that participated in this operation are: Vanuatu Agricultural Research and Training Centre (VARTC); Philippines Coconut Authority (PCA); Multi-Agro Corporation, Indonesia; and National Coconut Development Project (NCDP), Tanzania.

The results show that when water supply is not a limiting factor, or is only slightly limiting, radiation is the main factor that influences intercrop yields. Competition for water between the root systems of the coconut palms and the intercrop—in this case cocoa—was observed only in the event of marked water stress.

Collection of additional data required to develop a more comprehensive model of coconut palm functions is under way in Vanuatu. The data concern root system architecture, carbon distribution between the different organs, organ respiration, and transpiration flow.

The Natural Resources Institute (NRI), United Kingdom, has developed, in another project, a decision-support tool, based on data supplied by the coconut-based farming system model. It can be used, for instance, to estimate the economic advantages of intercropping with coconut over coconut monocropping under given agronomic and economic conditions.

An ecophysiologist has been posted in Vanuatu to pursue and expand the data collection operation. The researcher will also participate in the research and development project for optimizing coconut-based farming systems in Vanuatu.

biotechnology for coconut improvement

Further development of coconut cultivation is based on both the application of improved crop management sequences and the use of high-yielding, disease-tolerant varieties. Breeders use different techniques to maintain, utilize, and characterize the extensive genetic diversity of coconut. CIRAD manages a database containing information on the origin, morphology, and agronomic

behaviour of germplasm collections in 17 countries; the database was established within the COGENT network launched by the International Plant Genetic Resources Institute (IPGRI). Morphometric and agronomic data are informative but subject to environmental variations, which complicates comparison. As molecular markers do not have this drawback they are better suited for germplasm structural studies.

Different approaches have been adopted by research teams across the world to study molecular diversity. CIRAD uses restriction fragment length polymorphism (RFLP) to study some 40 ecotypes from the collection at the Marc Delorme research station in Côte d'Ivoire. The ecotypes are representative of the main coconut-growing regions. Two main groups of Tall cultivars have been identified. The larger group corresponds to Talls from Southeast Asia and the Pacific and the other to cultivars from South Asia and western Africa. There are marked differences between the two. In addition, there are three cultivars from eastern Africa and the Andaman Islands that present intermediary characteristics. Dwarf cultivars can be classified in the first group as they have numerous shared markers, suggesting a common origin, probably located in Southeast Asia.

Another DNA polymorphism analysis method, using microsatellites is also being tested. A set of microsatellites developed by the Long Ashton research station in the United Kingdom were supplied for the studies. A comparison of the RFLP and microsatellite marker techniques, carried out jointly with COGENT and the European organization BUROTROP, confirmed that microsatellites can now be used for routine diversity studies. CIRAD is developing its own microsatellites to add to the existing markers. The aim now is to involve other countries in this cooperative effort for the purpose of establishing a standard protocol for molecular diversity studies and integrating the results into the international database. This will increase the efficiency of coconut germplasm management worldwide.

rubber

rubber agroforest improvement in Indonesia

Rubber agroforests are plantations of rubber combined with fruit or timber trees, intercrops, or secondary vegetation, depending on the system. For the past four years, CIRAD has been working on a rubber agroforestry project, in collaboration with the International Centre for Research in Agroforestry (ICRAF) and GAPKINDO, an association of rubber processors. The smallholder trials were conducted on a participatory basis in 100 plots spread across western Sumatra, western

Jambi, and western Kalimantan, and in 13 experimental community budwood gardens. The trials led to the improvement of rubber agroforest management techniques for the crucial first three years after planting.

In savannah zones colonized by *Imperata cylindrica* (cogon grass), ongoing research focuses on intercropping of rubber with cover crops or fast-growing pulp trees, so as to control *I. cylindrica* growth by shading. The success rate directly depends on how organized the producers are. This was evident from results in the experimental budwood gardens managed by local communities, whose aim is to reduce production costs of clonal planting material. New trials are under way to test the possibility of using Ethrel stimulation to lower

tapping frequency from once every 2 days to once every 4 days.

Socioeconomic surveys of farming systems were conducted in 23 villages in western Kalimantan on 450 farms not covered by development projects. The surveys supplied substantial information about the problems faced by producers in adopting new techniques and on the strategies they use in different situations (cleared forest land, traditional rubber-growing regions, transmigration areas). The information also served to establish a typology of the different farming systems based on producer strategies.

Another series of surveys is under way among smallholders involved in rubber development projects, including transmigration programmes. They focus in particular on cases in which inputs are supplied without extension support or technical information. The surveys already indicate the proportion of farms that use forestry practices compared with those using the dominant monocropping model.

resistance of rubber to Microcyclus

The *Microcyclus ulei* fungus is the main obstacle to the development of rubber cultivation in Latin America; it is also a threat to the future of natural rubber in Asia and Africa. CIRAD is ideally placed to undertake a research project on the disease—the only such project at present—because of its base in French Guiana; it has already worked extensively on the crop in Guatemala, Mexico, and Colombia, and with the French Michelin group in Brazil.

Since 1985, it has been studying the nature of the genetic sources of resistance and the characteristics of the host–parasite interaction; its aim is to identify parents with resistance components that can be used over the long term. Its cooperation with Michelin since 1992 has led to the establishment of a clone creation programme in Brazil, aimed at finding a balance between fungus resistance and yield. Several sites have been identified for field trials.

Studies on a set of rubber clones revealed substantial differences in pathogenicity between fungal isolates. Clones selected in the field were tested under controlled conditions for their resistance to multivirulent isolates. RAPD (random amplified polymorphic DNA) molecular markers were used for identifying fungal isolates, structuring their genetic diversity, and characterizing their development in the field.

Over 700 RFLP and AFLP (restriction and amplified fragment length polymorphisms) markers were used for drawing the genetic map of a progeny from a cross between a high-yielding hybrid clone susceptible to *Microcyclus* (PB 260) and a hybrid clone resistant to a large number of isolates (RO 38). Based on the map and the results of inoculation trials using six isolates, nine significant QTL (quantitative trait loci) associated with different degrees of resistance were identified on 7 of the 18 chromosomes of *Hevea*. The strongest QTL accounted for

growing rubber in nontraditional areas of Southeast Asia

Southeast Asia is still the world's leading producer of natural rubber. But the increasing demand raises the risk of shortages. The main rubber development projects in the region are therefore moving into areas such as northeastern Thailand, Cambodia, and the Vietnamese highlands, but climatic conditions in these areas are less conducive to the crop than in traditional zones.

Many of CIRAD's expatriate researchers working on rubber have been transferred to these three countries. One of the research projects focuses on the development of cropping systems adapted to the new climatic conditions and to the smallholder sector. Other partners in this project are Kasetsart University, Thailand, and the rubber research institutes of Thailand, Cambodia, and Vietnam. The bilateral agreements signed with the partner organizations could eventually be integrated into a more effective regional cooperation structure for carrying out ongoing and future research operations.

10–35% of phenotypic variation. All the identified QTL were derived from the female parent of RO 38 (clone F 4542); it belongs to the *Hevea benthamiana* species, which has always remained resistant. Field evaluations of the progeny are under way. The results prove that it is possible to build total resistance by combining several genetic factors.

oil palm

conformity of oil palm clones: a molecular approach

Oil palms produced by in-vitro vegetative propagation can increase yields by around 25–30%. CIRAD, in collaboration with the French research organization IRD, and several public and private partners, established oil palm ramet production units in Africa and Southeast Asia. Several hundred oil palm clones were produced. However, in the experimental plantings a floral morphogenesis abnormality was discovered; it is caused by in-vitro culture and leads to plant sterility. This mantled abnormality is characterized by abnormal development of the female flower staminodes into six fleshy parts, which are morphologically similar to carpels and surround the gynaecium.

CIRAD therefore undertook systematic observations of the plant material produced in vitro. It could thus determine the frequency and severity of the abnormality and assess the behaviour of abnormal palms.

The abnormality affects around 10% of the material planted in Côte d'Ivoire and Malaysia. Its rate of occurrence in clones varies considerably; in certain clones it can reach up to 85% of the palms, which produce few, if any, fresh fruit bunches. Not all the flowers on a given palm are necessarily affected, and it can take up to 10 years after the first flowering for the abnormality to disappear. For the time being, it is impossible to detect the problem until the first flowers appear, and as this happens 2–3 years after planting, it is already very late.

CIRAD is selecting molecular markers in an attempt to detect and thus eliminate abnormal palms earlier on. This research programme is conducted jointly with IRD and the University of Paris XI, with support from the Palm Oil Research Institute of Malaysia (PORIM).

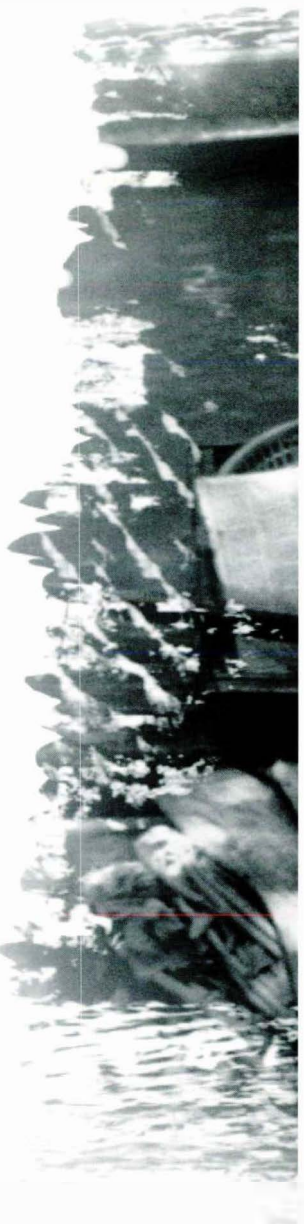
The in-vitro culture techniques used for the research were found to modify genome expression. The plan now is to alter the procedure to increase its efficiency.

palm oil: trade patterns and price fluctuations

Measuring, understanding, and forecasting changes in price volatility of palm oil has significant implications not only for importing and exporting countries that depend on a limited number of commodities, but also for farmers and traders, whose incomes are subject to constant fluctuations. CIRAD uses both econometric studies and historical analysis to study the situation. The econometric studies aim to date changes in palm oil price

volatility and the historical analyses retrace the history of the oils and fats market since the start of the nineteeth century.

The position of palm oil in traded oils rankings and the distance between the points of supply and demand provide a reasonable explanation for fluctuations in price volatility over the past two centuries. The market price of major oils is automatically more volatile than that of marginal products. Volatility is also high when the supply and demand points are geographically closer because the markets adjust faster. From a historical perspective of agricultural commodity markets, this is contrary to accepted theory and commercial arguments that market globalization and expansion will reduce volatility. In the nineteenth century, the oils market developed around long-distance trade between Europe and the Gulf of Guinea. However, since the 1970s, a new short-distance market has developed within Asia as a result of increasing oil and fat consumption in China, India, and Pakistan, and oversupply from Malaysia and Indonesia. The superimposition of the short-distance and initial long-distance markets automatically leads to unpredictable and increasingly wide fluctuations with the development of the short-term futures markets. This explains the current volatility on the world's commodity exchanges. But whereas these have a time perspective, the actual issue for tropical oil crops is one of geography.



Three important events marked the year for CIRAD-FLHOR, the Fruit and Horticultural Crops Department: the World Conference on Horticultural Research in Italy, the International Symposium on Bananas and Food Security in Cameroon, and the external review.

These events confirmed the relevance of the Department's research strategies. Its integrated approach to fruit and vegetable crop systems covers a wide range of parameters including consumer needs, product quality, nutritional value, and environmental issues.

In line with this approach, the Department develops economic analyses to investigate, for instance, price instability in urban fruit and vegetable supply networks. New processing techniques such as osmotic evaporation are also developed to enhance the nutritional quality and flavour of fruit products.

High priority is given to integrated farming systems, an important component of which is pest and disease management. In the Lesser Antilles, the Department's researchers design new methods for controlling Bemisia *whiteflies, which transmit virus diseases in solanaceous crops. A greater integration of all components of the farming systems is also sought for banana crops in the West Indies and vegetable crops in periurban areas.*

The focus of the Department's efforts is the novel commercial product that appeals to consumers. This implies the need for innovative methodological approaches that cover interactions throughout the commodity chain, from production to consumption.

Fruit and Horticultural Crops

fruit trees

salt tolerance in citrus

Soil salinity is a serious problem in citrus-growing areas, where soil degradation and decreasing yields affect more lands each year due to poor irrigation management and use of brackish water. Large regions are at risk, including the Mediterranean basin, where one-quarter of the world's citrus fruit crops are grown. Certain crop species and cultivars can tolerate hypersaline conditions, but citrus trees are sensitive.

Salinity has three types of adverse effects on plants. It causes moisture deficit by decreasing the leaf water potential of the soil solution; ion toxicity due to accumulation of Na^+ and Cl^- in the tissues; and nutrient stress due to competition between ion transporters (between sodium and potassium, sodium and calcium, chloride and nitrate, phosphate and sulphate).

Most studies on the physiological aspects of salt tolerance in citrus concentrate on the rootstock, where the exclusion and translocation capabilities of Na^+ and Cl^- ions can limit the effects of ion toxicity.

CIRAD physiologists follow a new approach by focusing instead on the role of scions in osmotic adjustment. Leaf cell water potential in the scions is lower than in the medium, so that water influx and turgour are maintained; in this way they are able to overcome water deficit.

Osmotic adjustment probably results from the accumulation of organic osmoprotective solutes (soluble glucides and polyol derivatives, amino acids such as proline and betaine derivatives) following neosynthesis. An analysis of a wide range of fruit trees under no-stress conditions confirmed that citrus trees have high but variable proline levels. If proline levels are found to be directly correlated with salt tolerance or sensitivity, the amino acid could be used as a biochemical marker in breeding programmes.

The first step involved in-vitro analysis to determine the conditions under which proline levels rise under stress following neosynthesis. *Citrus aurantifolia* leaf disks were submitted to osmotic stress by incubation in polyethylene glycol and to salt stress in an NaCl-supplemented medium. Proline levels increased under both conditions, but to a greater extent under osmotic stress. The response was weaker in the sodium-based media and declined after 24 h of incubation. The conclusion is that, for *C. aurantifolia,* the proline response is associated with osmotic stress and that its intensity is limited by sodium.

In the second step, the leaf disk test was carried out on 10 cultivars with known salt tolerance or sensitivity to establish a correlation between their tolerance/sensitivity and intensity of the proline response. The salt-tolerant cultivars showed low proline accumulation and high intracellular potassium levels, indicating a favourable potassium:sodium ratio. In this study, the proline response was associated with sensitivity to salt stress. Proline could therefore be used as a biochemical marker for salt sensitivity.

The study was carried out in collaboration with the University of Rennes I, France, which has developed a biotest for in-vitro incubated leaf disks. It will be followed up with a more detailed analysis of metabolic mechanisms involved in the proline response and a genetic study of osmoregulatory mechanisms.

fruit juice concentration by osmotic evaporation

three processes are currently used for juice concentration in the fruit juice industry. Thermal evaporation is by far the most common, but it causes product degradation and aroma loss, which cannot be completely remedied by vacuum processing and aroma recovery systems. Standard membrane filtration, involving reverse osmosis and ultrafiltration, reduces aroma loss but concentration levels are limited to around 40 °Brix. Freeze concentration ensures high organoleptic quality, but concentrations are only slightly higher at 40–50 °Brix.

Osmotic evaporation is a new membrane process that offers the advantage of concentrating water-based solutions at normal room temperature and atmospheric pressure. This simple and cost-effective technique not only conserves aroma but is also suited to processing fragile, thermosensitive solutions. The processed juices have a high soluble dry solids content (65 °Brix), and there is little or no solute loss. Osmotic evaporation thus offers many improvements compared with standard processes.

The basic design consists of a porous hydrophobic membrane (with air-filled pores), which is placed between the water-based solution to be processed and a highly concentrated saline solution. Water activity in the saline solution is very low because of high salt concentration. The difference in water activity in the two liquid compartments spontaneously creates a partial pressure gradient of water in the air that fills the membrane pores. The gradient causes the water molecules from the water-based solution to pass through the membrane in vapour phase. The basic physical phenomenon in this process is evaporation. Water actually evaporates at the interface between the solution to be concentrated and the membrane pores; it is transported as vapour through the pores and recondenses at the other interface between the pores and saline solution. All nonvolatile molecules—sugars, organic acids, mineral salts, vitamins, etc—are thus withheld. Transport of the different volatile molecules is determined by the liquid–vapour balances in the two solutions.

Mass transfer mechanisms for this type of process have not been studied to date. Such studies would be useful for improving the performance and specificity of the process for future industrial development. CIRAD, the University of Montpellier II, and the French food science and technology school, ENSIA, carried out a series of tests of sample solutions on a pilot module specifically designed for this purpose. The aim was to model vapour flow and monitor the behaviour of the main aroma components during concentration.

The results of about 20 tests conducted with different fruit juices (passion fruit, orange, blackberry, lime) supplied by producers confirmed the advantages of the process, particularly when combined

tropical fruit seminar in Nouméa

Tropical fruits ensure food security and balanced diets in the South Pacific region. They are also important sources of income as trade in these fruits is growing rapidly in domestic and export markets.

The Secretariat of the Pacific Community (SPC) and CIRAD jointly organized a seminar on "Overcoming Constraints to High Quality Tropical Fruit Production in the Pacific Region", which was held in New Caledonia in November 1998. The aim was to review the entire tropical fruit industry and research activities and to evaluate the technical and commercial aspects of fruit production. Around 40 researchers and decision makers from the public and private sectors from throughout the region participated in the seminar.

The seminar provided an opportunity for CIRAD to establish and strengthen partnerships in the South Pacific, especially with New Zealand. Participants also visited CIRAD's fruit research station at Pocquereux, New Caledonia, which is widely recognized as a regional training centre.

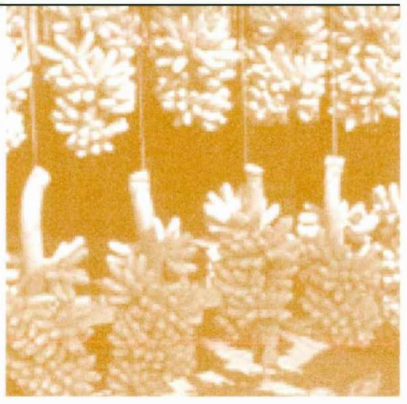
with a suitable pretreatment. The fruit juices obtained through this process are of excellent quality, with high concentration of around 65 °Brix, and without any product degradation or aroma loss. The process would find a large market in the food industry as it can be used for concentrating fruit and vegetable juices, skimmed milk, coffee extracts, unfermented and fermented wines, and ferments. It also has applications in other industries such as pharmaceuticals and cosmetics (plant extracts) and laboratory supplies (proteins, thermosensitive enzymes).

However, the costs involved are still too high for processing raw materials that can be concentrated by conventional techniques as the flow density is still too low. But it is certainly a better option for thermosensitive products or solutions that cannot be concentrated by other processes.

Four European companies will conduct further tests, mainly concentration trials, and three South American companies (from Colombia and Brazil) are interested in its large-scale applications.

banana and plantain

integrated banana production in the West Indies



Intensive monocropping of dessert banana can be detrimental to the environment. In most banana-growing areas, this strategy involves massive application of chemical inputs (mainly pesticides, fertilizers). Inadequate management of these inputs can cause physical, biological, and chemical degradation of the environment and affect the health of farm workers.

For several years, CIRAD has concentrated its efforts on solutions to improve the situation. Its crop management sequences are designed for integrated banana production strategies involving environment-friendly chemical, cultural, and biological control, and variety diversification. These strategies should be combined with measures to protect natural environments, to improve working—particularly sanitary—conditions on banana plantations, and to increase stakeholder awareness.

For leaf spot disease control, CIRAD has developed methods based on action thresholds that reduce the number of fungicide treatments. The methods involve weekly disease monitoring and counting so that crop protection services can schedule treatments more accurately. CIRAD also recommends alternate applications of different types of systemic fungicides, which should be mixed with fungistatic oils for longer effect than with contact pesticides. In this way, total annual applications can be reduced to only 0.5–2 kg/ha of active ingredient (4–8 treatments), instead of a minimum of 15 kg of active ingredient (up to 50 treatments) for contact fungicides in some regions.

To control nematodes—particularly *Radopholus similis*, which causes severe damage to banana crops—CIRAD recommends a cropping sequence comprising rotation with nonhost legume or grass crops and at least 1 year of fallow. These practices, combined with planting of healthy micropropagated plantlets, can reduce nematode inoculum levels in plantation soils so that nematicide treatments can be reduced or discontinued during the first two crop cycles. As in the case of leaf spot disease, CIRAD also recommends root nematode

counts to determine treatment thresholds, alternate treatments with different nematicides to avoid the evolution of resistant nematode populations, and selection of less toxic nematicide molecules to reduce pollution of runoff.

CIRAD has undertaken banana improvement programmes to create disease- and pest-resistant varieties. They focus on expansion of the genetic base of export bananas and use biotechnologies such as somatic embryogenesis for micropropagation. Three hybrids are currently being validated in the West Indies and at local research centres in Australia, South Africa, and Cameroon.

These proven techniques can reduce environmental risks associated with intensive monocropping of dessert bananas. In the West Indies, they can limit environmental pollution, save energy, prevent the development of resistant races or populations of parasites, reduce production costs, and enhance sustainability of banana cropping systems.

banana and food security

Research on banana, particularly on varieties for local consumption, does not reflect the significance of the crop as one of the main food resources in the world, with an annual production of 86 million t. This observation led to the organization of the International Symposium on Bananas and Food Security, which was held in Douala, Cameroon, in November 1998. The Symposium was attended by 120 participants from different countries.

The importance and diversity of bananas for local consumption were viewed for the first time from a socioeconomic standpoint. Local bananas account for more than 80% of total banana production worldwide The Symposium also aimed at drawing the attention of policy makers from banana-producing countries and donors on the importance of banana-based products for food security in many Southern countries.

The general opinion of participants was that consumers' requirements should receive more attention from all operators involved in the banana industry and that producers should have access to new outlets for their produce. They recommended that research on sustainable production should be strengthened and that efforts to link production areas to distribution channels should be intensified to ensure regular supply and stable prices to consumers. Participants suggested that market observatories should be set up in banana-producing countries to monitor demand–supply patterns. They also suggested that the product range should be diversified to develop new markets.

The Symposium was organized by the regional banana and plantain research centre for central and western Africa CRBP, and the International Network for the Improvement of Banana and Plantain (INIBAP), in collaboration with the Technical Centre for Agricultural and Rural Cooperation (CTA) and CIRAD. It was held under the aegis of the Cameroonian Ministry of Scientific and Technical Research and supported by the European Union, the French Ministry of Cooperation, and the FAO.

SIA, the international agriculture fair in Paris

Banana was the theme selected by CIRAD for the third year of its participation at SIA, the international agriculture fair in Paris, in March 1998. On this occasion, CIRAD highlighted its experience of more than 50 years of research on banana and its know-how on all aspects of this sector. The fair also offered an opportunity to inform the general public on this very popular but still poorly understood crop. The event involved the collaborative efforts of the French office for development of the rural economy in overseas departments ODEADOM, INIBAP, and CIRAD's subsidiary Vitropic that markets micropropagated plantlets. The meeting on "Bananas and the Environment" organized at SIA was attended by about 100 specialists.

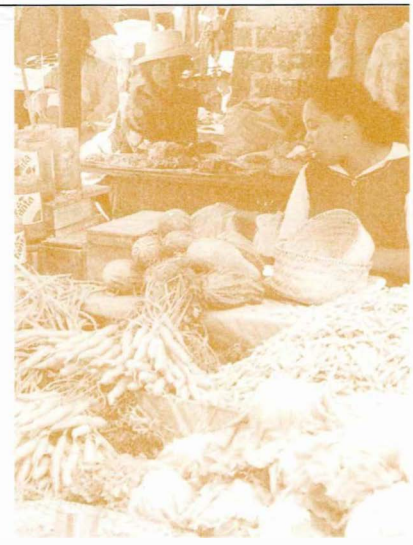
horticultural crops

whiteflies in the Lesser Antilles

During an outbreak of *Bemisia* whiteflies in the Lesser Antilles in 1990, new types of damage were observed on the infested crops: silvering of zucchini, ripening defects and virus diseases in tomato. These diseases had been hitherto unknown in the region. *Bemisia* whiteflies are known to induce physiological disorders in host plants and to transmit certain viruses, particularly geminiviruses. In-depth studies of the *Bemisia* complex in the Lesser Antilles had to be undertaken to determine whether or not the observed damage could be attributed to these sucking insects.

CIRAD and the local crop protection service sampled whitefly populations from several different crops and sites. The specimens were used for characterizing the populations based on morphological studies mainly of the waxy marginal fringes of nymphs and on electrophoretic analysis of esterase. Laboratory reared insects were used for studying biological parameters (development time, longevity and fecundity, sex ratio, and behaviour on various host plants) and the pest's damage potential for different crops.

The findings indicate that most of the whitefly populations in the



Lesser Antilles belong to the B biotype of *B. tabaci*. Certain authors consider this biotype to be a separate species and name it *B. argentifolii*. The biological and biochemical characteristics of these whitefly populations, especially their ability to induce silvering symptoms in zucchini under experimental conditions, support this hypothesis. The N biotype of *B. tabaci* was also identified, but it seems to infest only *Jatropha gossypifolia*.

Parallel collaborative studies on the Lesser Antilles geminiviruses were conducted in the West Indies with the French agricultural research institute INRA, in the United States at the University of Florida, and in Colombia at the International Center for Tropical Agriculture (CIAT). The results confirmed that the new virus disease of tomato that appeared in 1992 was linked to the proliferation of *B. argentifolii* populations. The new virus was identified as the potyvirus, and cage trials have demonstrated that this virus can also be transmitted by the whitefly.

But this research will only be relevant if it leads to the development of rational control techniques. One of the techniques is based on the use of the natural enemies of this pest. About ten potential predators, five parasitoids, and one entmopathogenic fungus were identified from a survey in the West Indies. The predatory and parasitic behaviour of the different insectivores was studied to evaluate the possible impact for whitefly control strategies. The beneficial role of some of these natural enemies (*Encarsia* spp., *Eretmocerus* sp.) in controlling whitefly populations was confirmed.

This research has already led to the development of a rational strategy for controlling *B. argentifolii*. In Martinique, integrated pest management, including the use of natural enemies, has reduced whitefly infestation levels and virus disease incidence in tomato crops.

stabilizing food supply to urban markets in Africa

In Africa, increases in crop and livestock production are still not sufficient to meet the needs

of growing urban populations. Consumers are forced to rely on imported foods despite their preference for local products because of irregular food supply, uneven quality, and volatile prices, which for some products can triple within a year.

A multidisciplinary research project was launched in 1995 to analyze this fluctuating situation, determine its causes, and assess the strategies adopted by public and private organizations to address these problems. The project was coordinated by CIRAD and involved two French universities (Saint-Quentin-en-Yvelines and Paris I). The studies in Cameroon were conducted in collaboration with CRBP, the regional banana and plantain research centre for central and western Africa, and in Guinea with the food security programme of the Ministry of Agriculture.

Product flow and prices were analyzed for several food products: rice (staple food) and onion in Guinea; rice, onion, plantain, tannia, cassava, yam, and tomato in Cameroon. Data collected through the surveys in the two countries were used for analyzing supply patterns, assessing different types of market organization, and understanding consumer preferences.

Prices of domestic products, unlike those of imports, were found to vary substantially. Those due to seasonal supply and high demand during festivals can be anticipated. Others due to climatic events, diseases, and product spoilage during shipping, storage, or distribution are unpredictable. The real cause of price fluctuations is the short duration of production periods rather than hoarding practices by retailers.

In Cameroon, wind damage and weevil infestation force farmers to harvest plantains in March–April before they are ripe and dump them on the market, which leads to shortages until August. In Guinea, domestic onions from the *bas-fonds* (inland valleys) are available only during the 6-month harvest period from March to August because sowing is limited to 3 months from November to January. Sowing could be staggered if farmers had access to fields that are not prone to seasonal flooding and they had the funds for early sowing. The harvest period could also be extended if farmers were not under pressure to sell their produce because of lack of cash.

Many problems of distribution arise from irregular supply of produce. Traders are forced to diversify their income and cannot carry out their activity professionally. They raise margins on some products to offset reduced turnover during less active periods. Farmers' groups have established centralized assembly and distribution organizations, but they set prices and volumes before the crops are harvested and do not adjust to fluctuations in demand. This

sustainable periurban agriculture

Periurban agriculture is becoming an increasingly important source of fresh produce for urban dwellers, who spend most of their income on such products. But this activity is still not very stable. Efficient management of periurban space will ensure agricultural sustainability, a steady income for farmers, and a regular supply of fresh food to urban markets.

A workshop on periurban agriculture in sub-Saharan Africa was organized in Montpellier from 20 to 24 April 1998 by CIRAD and CORAF, the conference of agricultural research coordinators in western and central Africa. Around 40 representatives of African research and development organizations and Northern research institutions attended and reviewed the work undertaken in this field. New themes were identified, such as rules for resource sharing and environment-friendly intensification of crop and livestock production.

inflexibility explains why farmers have shifted from collective to individual marketing.

The overall economic environment is also an important factor. In Guinea, the development of road transport has stimulated food crop production. Onions are a recent introduction; protectionist measures to control imports have benefited sale of local produce and given farmers the incentive to increase production. Moreover, improvement of the telecommunications system has greatly facilitated information exchange between assembly markets, wholesalers, and retailers.The findings of this research will be published and circulated to all who participated in the project so that they can validate the action priorities.

In 1998, CIRAD-EMVT, the Animal Production and Veterinary Medicine Department, was restructured into three programmes to pursue more effectively its work on the development of animal production in the tropical and subtropical regions. The Rangeland and Wildlife Management Programme focuses on sustainable management of natural resources used by domesticated or wild animals and on ways to conserve animal biodiversity. The Animal Production Programme is concerned with production systems, their improvement and economic aspects, and modelling of the systems. The Animal Health Programme develops diagnostic tools and methods for controlling major tropical diseases.

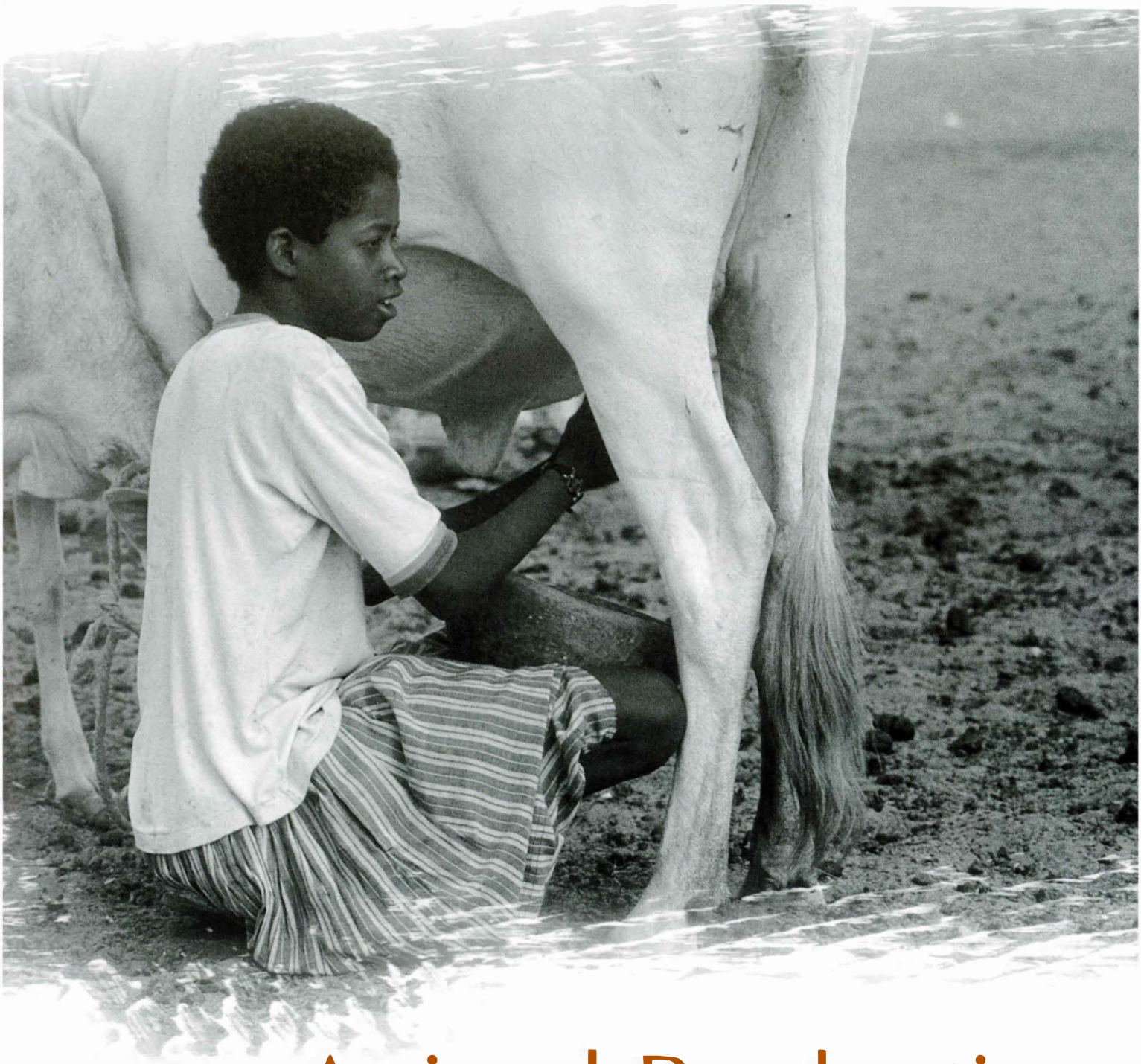
The Department's strategy has a strong regional focus, which it develops through its programmes and with the support of the laboratories and research teams in Montpellier. It has well established regional programmes in Africa: in Burkina Faso for subhumid savannah zones, in Senegal for dry zones, in Zimbabwe for southern Africa, in Kenya and Ethiopia for eastern Africa, and in Madagascar. Other programmes are located in Southeast Asia and in the Caribbean.

Control of diseases transmitted by the tsetse fly and ticks as well as aquaculture remain the major thrusts of the Department's activities. To these have been added new priorities: disease epidemiology, animal production economics, and wildlife management and enterprises.

The Department has been designated by the FAO and OIE, the world organization for animal health, as a regional and international reference laboratory, in recognition of its long-standing experience and achievements in livestock diseases. It has been given this responsibility for tropical diseases such as contagious bovine pleuropneumonia, peste des petits ruminants, and contagious caprine pleuropneumonia, as well as trypanosomosis epidemiology and tsetse fly control.

The Department's policy of partnership is implemented through the establishment of a large number of collaborations with organizations in Africa, Asia, Europe, and France and international centres. In particular, framework agreements were signed with CNEVA, France; CIRDES, Burkina Faso; and ILRI, Kenya. Joint activities have also been developed with INRA, France; agricultural research systems in Africa; and Asian universities.

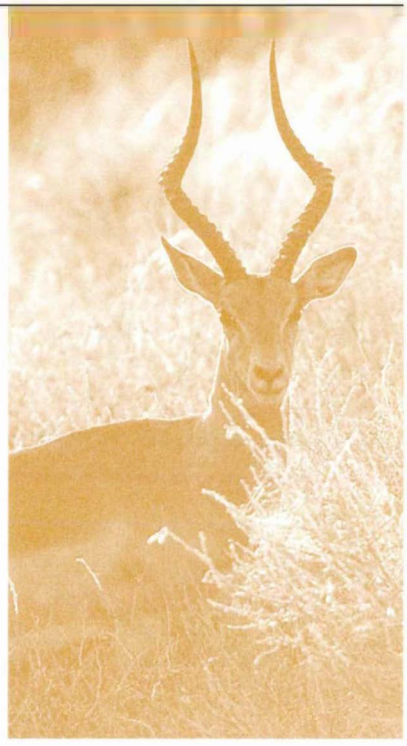
The Department's formal education activities are being adapted to European and international norms. A European master's programme in animal production and a veterinary specialization in tropical pathology were established. Training, a key activity of the Department, is increasingly developed through associations with universities in an effort to enhance France's contribution in the field of professional training in livestock production, animal health, and wildlife.



Animal Production and Veterinary Medicine

rangeland and wildlife management

livestock–environment interactions: tools and indicators



Projections for the next 25 years indicate a steep increase in demand for animal products, particularly in tropical and subtropical countries. This raises the question of the extent and conditions of the impact of domesticated animal production on the environment, particularly the risks. Several international development organizations have expressed the need for guidelines and tools for directing their work towards a sustainable and environment-friendly mode of production. They seek the guidance of researchers specializing in livestock production and ecology, as well as economics and social and political sciences.

In 1993, a study group was formed on the initiative of the World Bank to review the environmental risks involved in livestock production. CIRAD participated in a detailed study conducted in collaboration with several European research organizations—GTZ, Germany; NRI, United Kingdom; IAC, The Netherlands. For the study, CIRAD focused on the extensive livestock systems in the tropical areas of Africa and Asia, the mixed crop and livestock production systems in the sub-humid tropical zones, as well as the impact of animal production on deforestation.

Extensive livestock production on rangelands and grassland, which uses large open areas and natural vegetation, occupies almost one-quarter of all available land and competes with cropped lands and forests for space. Tropical rainforests are being deforested at an average annual rate of 0.9%, and between 11% and 20% of this deforestation can be partly attributed to the expansion of extensive livestock production systems. In the mixed crop and livestock productions systems, the livestock component recycles part of crop produce, mainly residues; in this way the animals are not only a source of revenue, but also provide inputs in the form of traction energy and manure. Intensive livestock systems require little space but very substantial inputs (feed); they also produce very high amounts of waste that have to be processed and recycled. The world's cattle population is estimated at 1.3 billion heads; between 0.5 and 5 ha per head are needed to feed it.

The ecological imbalances caused by livestock production are due to both direct and indirect effects. Economic, social, institutional, and political factors also have an impact. Financial concerns often determine the options chosen by livestock farmers. In the countries of the Sahel, after the devaluation of the CFA franc and the subsequent increase in meat prices, farmers' incomes rose without any need to increase the size of the herds. Institutional factors also affect the implementation of environmental measures.

The information collected by the study group was compiled in a report, which was completed in 1997 and presented at an international meeting held in Wageningen, The Netherlands.

The scientific and technical recommendations contained in

the report need to be translated into action. The FAO has called upon three European research and development organizations—NRI, IAC, and CIRAD—to prepare a toolbox intended for those responsible for the development of livestock production, donor agencies, and project directors.

The simple and user-friendly toolbox will be published as a CD-ROM. It will also be hosted on an Internet site. It is made up of five parts, with numerous hyperlinks.

The first part groups the elements needed for assessing the direct impact of animals on soil, vegetation, water, and biological diversity. In the list of indicators, those that are quantifiable are presented along with the corresponding methods for measuring the parameters. For arid zones, where the major risk is desertification, indices were established for measuring soil degradation based on studies of vegetation, erosion, and loss of soil fertility. However, the evaluation criteria vary considerably with the agro-ecological zone, and their selection and relevance will depend on the context in which they will be applied.

The second part is devoted to the role of institutions in environment conservation. The erosion of traditional structures and changes in land tenure and access to resources warrant the establishment of farmers' organizations and a sharing of decision-making powers.

The third part covers the short- and long-term consequences of policy decisions related to the development of livestock production. Incentives and regulations figure prominently as they are the only tools that governments can use to check misuse or uncontrolled use of resources. Among the measures listed in the toolbox are support to farmers' organizations, environmental monitoring methods, and subsidies to compensate for environment conservation measures.

The fourth part concerns technological advances, which should now aim not only to increase production but also to reduce negative environmental impact.

The fifth part deals with stakeholder awareness campaigns on environmental issues related to livestock production and integration of environmental issues into university prgrammes.

Just as policy makers draw on research work for formulating strategies, researchers should also share the concerns of decision makers in development activities. Researchers need to update decision makers on the real issues through a lucid and accessible analysis of the situation. To present a comprehensive view, the teams should be made up of specialists from different disciplines and origins, and with complementary experiences and skills.

wildlife and rinderpest control

*Rinderpest affects both domesticated and wild ungulates. This viral disease is highly contagious, and mortality rates can sometimes reach 80%. For the past 14 years, the PARC project has led a campaign against rinderpest in Africa. In 1994, an epidemic affected populations of African buffalo (*Syncerus caffer*) and kudu (*Tragelaphus imberbis*) in Tsavo National Park in southern Kenya. Laboratory analyses revealed that the virus line II caused clinical disease in wildlife but not in domesticated animals, and it was hardly detectable in cattle samples. Wildlife therefore offers the best means for monitoring epidemiology of this virus strain.*

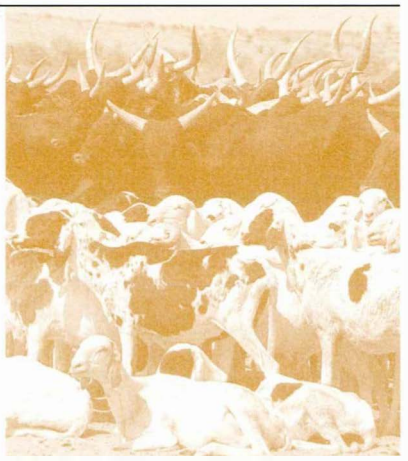
In 1998, a large-scale epidemiology survey of wildlife was launched in the most exposed areas of Africa. The sampling campaign covered central and eastern Africa (Burkina Faso, Central African Republic, Chad, Democratic Republic of the Congo, Ethiopia, Kenya, and Tanzania). The campaign was financed by the European Union, and coordinated by CIRAD. By May 2000, more than 1000 wild ruminants will be captured and anaesthetized for sampling. The results will allow a better understanding of rinderpest epidemiology for strengthening eradication measures among both wild and domesticated animals.

animal production

supplying local milk products to cities

In the cities of the South, demand for milk products is rising as rapidly as the populations—between 3% and 8% annually. Formal and informal sectors are emerging locally, capitalizing on the appeal of local products and the advantages of new technology. In western and central Africa, the devaluation of the CFA franc in 1994 made domestic products more competitive vis-à-vis imported powdered milk and thus stimulated the local milk industry. In dry zones, particularly in the Sahelian countries, camel milk is emerging as a new sector.

In September 1998, CIRAD organized an international workshop on supply of milk products to cities in Africa. It brought together researchers, private entrepreneurs, and representatives of nongovernmental, national, and international organizations. The workshop marked the completion of a research programme launched by CIRAD in 1994 in collaboration with the French research organization INRA, the Chadian veterinary research laboratory LRVZ, and the International Livestock Research Institute (Ethiopia). Case studies on Brazil, Mauritania, and Morocco were also reviewed at the workshop. The presentations and discussions focused on the technological, economic, and sociological aspects of the complex traditional sectors, and explored options for improvement.



Supply of milk products to the cities is characterized by the diversity of products, economic situations, and socioprofessional networks. Driven by a dynamic small-scale processing sector, local industries maintain their competitiveness and continuity by offering traditional and quality products. Consumers are often willing to pay a higher price for local products than for imported goods because these products meet their specific, traditional requirements.

In Ethiopia, for example, there are many types of traditional butter: cosmetic butter, fresh cooking butter, semirancid and rancid butter. These farm products are brought in from the high plateaux to the cities and sold on traditional markets by networks of traders using diverse distribution strategies. Typical products and high quality—confirmed by laboratory tests—make the traditional sector highly competitive vis-à-vis the periurban units of the formal sector and imported products. In Addis Ababa, for example, the traditional sector has a market share of 65%.

In Chad, milk is traditionally processed either by heating or curdling so that it keeps longer; one of the main products is curdled milk. Research undertaken on lactoperoxidase contained in cow's milk identified the conditions in which this natural enzyme is activated and extends the life of raw milk. The technical frame of reference that was developed opens new perspectives for milk collection to meet growing demand.

In those parts of Africa where repeated droughts and an increasingly dry climate are not suitable for cattle, camels are seen as a replacement solution. In Morocco, periurban animal production in Laâyoune is gradually evolving from the originally extensive form of production into an intensive system, under the impact of new herd management and feeding methods. It now meets the growing demand of this regional centre. Camel milk accounts for 30% of milk supplied to Nouakchott, the capital of Mauritania. Improved technologies have contributed to the increasing importance of camels.

Processing of camel milk into cheese, which is normally a difficult operation, is now made possible by new techniques. A private Mauritanian dairy requested the assistance of CIRAD researchers to test the efficiency of their process for pasteurizing camel milk. A simple test based on an enzyme marker was developed to guarantee product quality; as a result, sales have increased.

Another asset of the traditional milk sector is the dynamism of small-scale processing units. Minidairies process a daily volume of milk varying from 200 litres to 1000 litres. They are run by private entrepreneurs or are connected with groups of small producers, from whom they collect milk thus encouraging them to increase production. In many African countries, such as Mali, small dairies have been established in secondary towns to process local milk output. Packaged and processed products are either sold directly by the dairy, or by women vendors. All players—producer groups, processors, collectors, and professional women vendors—are independent, but they can hold shares in the processing enterprise.

In Brazil, small-scale local cheese plants in particular have grown rapidly in the Nordeste region. They produce different types of soft and hard cheeses for which there is a high urban demand. The cheese plants ensure milk offtake and offer a profitable price to livestock farmers who are located far from the collection points of large dairies. For the milk suppliers in the semiarid Sergipe region this is an incentive to increase milk production. Such an agrifood system can serve as a model for milk-producing regions in other continents.

The small-scale plants need a legal status to insure continuity of their enterprise. This raises the issues of product quality and financial viability. In Mali, as in Brazil, after carrying out a quality diagnosis, CIRAD's researchers have developed processes for guaranteeing quality that are suited to the traditional local processing methods. These are necessary steps for establishing local regulations that cover the range of situations.

Further research is needed to determine demand and production cost factors, animal feed requirements in intensified systems, genetic parameters of production, and social parameters in processing practices.

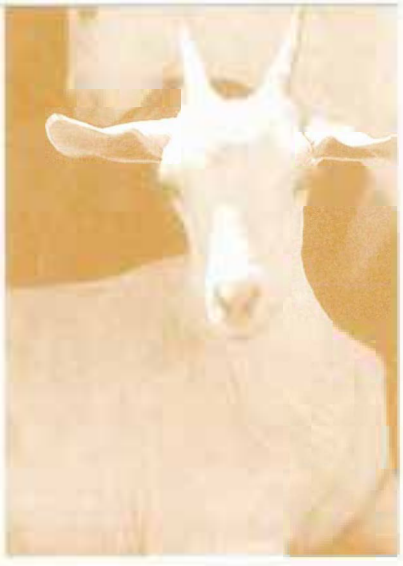
Research needs were also identified in Asia and could form the basis for new cooperation activities. In Kazakhstan, there is a need to improve quality and technology for traditional milk products and to better understand the socioeconomic dynamics of the sector. In China, there is a need to study yak and camel productivity and to assess options for processing milk.

French enterprises and the Ugandan milk sector

In Uganda, the demand for milk products from a rapidly growing population—3% per annum—particularly in urban centres outstrips supply, which grows at only 2.6% annually. In 1997, the French Embassy in Kampala financed a study of the sector, which the Ugandan government regards as a priority area. The government is therefore keen to encourage partnerships between French and Ugandan enterprises from both the private and public sectors. CIRAD undertook a diagnosis of the animal and milk production sectors. Several French private and cooperative groups—SERSIA and MIDATEST for genetic improvement, UFAC for animal feed, and SODIAAL for milk products—who are interested in business opportunities in Uganda are collaborating with CIRAD in development operations. In 1998, CIRAD established a facility for applied research in M'Barara, a rural area in the west of the country. The area has a sizeable market and favourable production conditions. It forms a potentially strong milk belt, away from large consumption centres. In sub-Saharan Africa, milk production in the periurban areas—where most current development efforts are concentrated—will not be able to fully meet demand, which is estimated at 43 million t by 2020. Other projects in which CIRAD will be associated with partners from the French and Ugandan private sectors are planned. Moreover, CIRAD's activities in Uganda have recently received financial support from the French development agency AFD and the French company PROPARCO.

animal health

combined expertise for epidemiological studies



The main challenge for animal health programmes the world over is to identify, organize, and coordinate specialized knowledge and experience, and to rapidly inform decision makers. Diagnosis and control of the main animal diseases are key components of the global strategies adopted by international organizations. Disease control in this case aims at maintaining herds in good health, reducing production costs, and protecting consumers. Epidemiological studies should therefore also consider the economic and public health repercussions of a disease.

CIRAD's expertise in epidemiology is recognized by many national and international organizations, including the FAO, OIE, and national centres in Africa.

The FAO has designated CIRAD as a world reference laboratory for contagious bovine pleuropneumonia and a regional reference laboratory (for Africa, Asia, and the Middle East) for peste des petits ruminants and contagious caprine pleuropneumonia. It is also a collaborating centre, in Africa, for strategies related to development and land use in tsetse fly-affected areas and for FAO's emergency prevention systems (EMPRESS) for Africa.

The OIE has designated CIRAD as a reference laboratory for rinderpest and peste des petits ruminants, and as a collaborating centre for contagious caprine pleuropneumonia and for diagnosis and control of animal diseases in tropical regions. Several CIRAD researchers also participate in epidemic surveillance networks in the countries of sub-Saharan Africa.

The participation of researchers from various disciplines in epidemiological research at CIRAD stimulates the development of new methods for research and analysis.

Both transversal and prevalence surveys are undertaken for monitoring diseases. Dysfunctions in animal herds are studied in the context of the animal production system and involve studies of farmers' practices, conditions of livestock production, and the environment.

Wide-ranging recommendations are proposed on the basis of ecopathological surveys that study the relationship between diseases and the environment. The surveys confirm the value of multidisciplinary approaches.

Ongoing surveys focus on the risk factors linked to infertility in milk cows in Réunion and the incidence of diarrhoea among young camels in Morocco. Observations are collected by a team of veterinarians, epidemiologists, animal and crop specialists, representatives of professional organizations, statisticians, and computer experts. The parameters are integrated into a database that reflects the complexity and diversity of the interrelated factors. A model of the disease is built step by step for assessing the relative importance of risk factors and health indices. The findings are shared with all the key stakeholders in the system through publications, workshops, and training sessions.

A novel approach, based on integration of remote sensing data into a geographic information system (GIS), has been developed for epidemiological studies of vector-transmitted diseases such as trypanosomosis and tick-borne diseases.

In one such survey, the factors for forecasting the distribution and intensity of two tsetse fly species were identified in an area of about 1000 km² in Burkina Faso. Findings from field surveys were linked to high-resolution satellite data (Spot images). The GIS combined different layers of geographically referenced data on entomology, vector and livestock parasitology, the natural environment, land use and changes therein, livestock distribution, and pastoral practices. Population trends for tsetse fly were studied on the basis of data of environmental changes observed through a succession of aerial and satellite images. The distribution of trypanosomosis vectors and their hosts was displayed graphically. Observations revealed a close relationship between certain landscapes shaped by agricultural use and the dynamics of tsetse fly populations. Areas of high or no risk of infection were identified as a result of the study. A GIS is thus an essential tool in precision targeting of actions to control vectors.

The study led to the development of a new approach to the study of disease systems. It is based on the combined use of LASER software, remote sensing, and GIS together with field studies. The LASER software created by CIRAD is an innovative tool in epidemiological studies; it processes the totality of livestock data for analyzing epidemic risks. Remote sensing information is linked to field survey data for obtaining various levels of insight, so that a reliable diagnosis can be made of the situation and appropriate recommendations can be proposed for action.

The Department also offers a range of training programmes in epidemiology. CIRAD conducts the molecular epidemiology course at ENVL, the veterinary school of Toulouse, France. It also organizes training courses in laboratory techniques and use of the LASER software in Montpellier.

At present, CIRAD is forming an interdisciplinary group with different types of field and laboratory expertise in epidemiological studies. This will encourage synergies between various areas of work and different research approaches. In this way, CIRAD will be able to respond more rapidly and effectively for the development of epizootic control strategies.

bovine dermatophilosis: molecular markers of genetic resistance and sensitivity

Dermatophilosis in ruminants is a skin infection caused by ticks, particularly *Amblyomma variegatum*. It causes serious herd losses, and efforts to control it have had little effect so far. Treatments with acaricides and antibiotics are expensive and more or less efficient, and induce chemoresistance. There is little prospect of developing an effective vaccine because the antibodies of the primary infection do not ensure adequate protection; moreover, the infection cannot be induced experimentally. Livestock farmers have few options because the disease also affects imported animals and crossbreeds.

For the past seven years, CIRAD has been conducting research on dermatophilosis, in partnership with European and African centres. Its project in Martinique is conducted in collaboration with INRA and private livestock farmers; it is financed by the regional authorities of Martinique, the French Ministry of Overseas Departments and Territories, and the European Union.

Livestock farmers in Africa and the Caribbean have observed that certain individual animals and breeds show natural resistance to the disease. The zebus of Madagascar, Creole cattle of the West Indies, and trypanotolerant breeds of Africa are more resistant than the European breeds. But the Sahelian zebus of western Africa are susceptible. In Martinique, the population of Brahman zebus, which was introduced from the United States 50 years ago, has shown a certain vulnerability after being exposed to the disease. These significant variations in reactions are not due to racial characteristics, but to natural selection of

vaccine against trypanosomosis in animals

Standard vaccination strategies are ineffective against parasitic diseases. A new concept, the "antidisease" vaccine, therefore aims to increase the host's resistance to the disease, rather than prevent infection by the parasite. African trypanosomes are extracellular and intravascular parasites that release their constituents in the host's bloodstream. The symptoms of trypanosomosis are produced by the toxic effect of these parasitic factors. Studies conducted by CIRAD researchers at ILRI, Kenya, revealed the possible role of parasitic proteases in disease development following infection by Trypanosoma congolense. *They observed that trypanotolerant cattle developed antibodies that were able to neutralize a cysteine protease. This type of enzyme could therefore be considered a possible candidate for a vaccine. Genes coding for two families of cysteine proteases were cloned, and recombinant antigens were produced. These were used to immunize trypanosusceptible breeds of cattle. When the animals were challenged with an experimental infection by* T. congolense, *they first showed classical trypanosomosis symptoms, mainly acute anaemia, and then their clinical condition improved steadily during the chronic phase. The immunized animals presented effects similar to those observed in trypanotolerant cattle: no change in body weight, lower levels of anaemia and immunosuppression. Studies to confirm these findings in a larger sample population are under way.*

subpopulations among breeds that have been present in endemic zones for a long time.

The prime objective of dermatophilosis research has therefore been to identify the relevant genetic markers from resistant and susceptible animals and to use them for genetic improvement programmes.

In Martinique, based on the results of a 7-year ecopathological survey on more than 1000 animals of the Brahman breed, several hundred unrelated (individual) animals were classified into two groups exhibiting the highest degree of resistance and the highest degree of susceptibility. The genetic situation of the breed was analyzed using biochemical and molecular techniques.

The identification and use of candidate molecular markers is a targeted approach based on knowledge of the precise genome map of the host animal species and of the biological mechanisms involved in infection and immune response of the host. Among the large number of molecules involved in the mechanisms at the host–pathogen interface, those of the major histocompatibility complex (MHC) are chosen as they control the mechanisms for presentation of antigens and for triggering host immune responses. The link between MHC and genetic, infectious (eg, mastitis or tuberculosis), or parasitic diseases has been reported in many studies on both humans and domesticated animals. The bovine MHC locus (BoLA), is located on chromosome 23.

A study of polymorphisms on BoLA class I and class II molecules, using different immunogenetic and biomolecular techniques, has yielded several markers. The most significant marker for susceptibility is an amino acid motive (ES) present in five alleles of the BoLA-DRB3 gene.

In the Martinique project, among the animals carrying this ES marker, 96.6% were susceptible. As the ES marker is present in only 60% of infected animals, more susceptibility markers are needed to refine marker-assisted selection. By eliminating ES carriers, the percentage of infected animals was reduced from 79% to 20% over a 3-year period. The herds continue to be monitored for occurrence of the disease, and similar linkages are sought in other targeted genetic systems.

Transmission of clinical characters of resistance and susceptibility, and of the identified molecular markers was studied in several test families of cattle. The families were composed from data provided by farmers on their herds. Affiliations were determined by using molecular biology techniques, since there are often several males in a herd. In both Martinique and Madagascar, the resistance or

susceptibility of the parent animals used for crossbreeding was known.

Subsequent research will seek to validate the molecular markers for resistance and susceptibility identified in the Brahman zebus of Martinique. One of the study populations will be of the same breed but from a different location (eg, Brahman zebu in Madagascar) and the other two populations will be of different breeds but with low susceptibility to dermatophilosis (eg, Creole cattle of Guadeloupe, trypano-tolerant Baoules of Burkina Faso). The research will also focus on the transmission of phenotypical characters of resistance and susceptibility to dermatophilosis and of genotypical (molecular) markers identified in test families (herds in Martinique, Madagascar, and Burkina Faso), as well as in the F_1 progeny from crossbreeding between resistant and susceptible animals.

The second session of the UN Intergovernmental Forum on Forests was held in Geneva in 1998. In accordance with the mandate set by the UN Commission on Sustainable Development, this session focused on the legal instruments for the management, conservation, and sustainable development of all types of forests. The debates at the session highlighted yet again the large number of key issues that have still to be resolved before an international consensus can be reached on the subject.

The Forum intensified its efforts by announcing many new initiatives, including the International Consultation on Research and Information Systems in Forestry to be held in Gmünden, Austria.

The forest fires in the state of Roraima, Brazil, again mobilized public concern about the combined impact of uncontrolled human activity and adverse climatic conditions on the fragile tropical forest environments. The international tropical wood market was also shaken by the financial crisis in many Asian countries, which seriously affected forest production not only in Asia, but also in Africa and Latin America.

It is against this rapidly changing background, that the three programmes of the Forestry Department, CIRAD-Forêt —Natural Forests, Trees and Plantations, and Forest Products—engaged in collegial discussions to define the structure of their research and support activities. The exercise is also useful for establishing and strengthening partnerships within CIRAD, and with other organizations in France, Europe, and the rest of the world.

Forestry

natural forests

automated design of a forest access system

Geographic information systems (GIS), which process geographically referenced data, are valuable tools for defining forest management options and harvest plans. The Department used IDRISI software to design a forest access system for skidding logs from the yards to the main road. The objective was to design a system that entailed minimum construction costs. The project is a component of the Sangha-Mbaéré forest management programme in the Central African Republic.

Felled trees are skidded to the nearest log yard. The yards usually serve an extraction area within a radius of 500–700 m and stock at least 1000 m^3 of timber. The logs are then skidded across the forest access system to the main road and then transported to the sawmill.

The goal is to collect timber as cost-effectively as possible, but the shortest route is not always the cheapest. Together with timber companies, the Department developed a system for calculating hauling costs depending on the physical constraints encountered in each situation. According to the system, the cost of overcoming a constraint such as a river or steep slope corresponds to the length of the detour that the timber company is prepared to construct.

Traditionally, roads were mapped manually on rough layouts that showed potential logging sites and topographic constraints. For the studies commissioned by the company Sésam, the Department conducted a forest inventory over 1500 ha to collect information on species composition and physical constraints. The data were spatially organized in pixels representing 25 m × 25 m. Trees belonging to three species—sapelli (*Entandrophragma cylindricum*), utile (*E. utile*), obeche (*Triplochiton scleroxylon*)—with a trunk diameter exceeding 40 cm were inventoried as usable or potentially usable timber.

The access system was designed using digitized data of the main features of the landscape: main road, watercourses, topography, and logging sites. Standard raster image data files were used to calculate distance costs—based on distance and constraints—for each pixel in the final image.

For the first method, the optimum route between the log yard and the main road was computed independently for each log yard, and then all the plotted routes were overlaid.

The second method involved an iterative process. At each step, the section for reaching the nearest log yard was added to the route and the yard was deleted from the list. The process is slower but it generates the most cost-effective and shortest system.

The results of the simulations were compared with the routes traced manually by foresters. The manual maps did not adequately account for the costs linked to constraints; the routes in this case crossed the obstacle instead of going around it. A comparison of the different designing methods revealed that the systems based on the iterative process were the most cost-effective.

In the third method, strategic sites were assigned as nodes. But although the final cost was lower, the method involved complex processing.

The next steps may include greater integration of forest inventory data in the GIS and automatic positioning of log yards. The entire simulation sequence will soon be available

in new user-friendly software packages that should facilitate the task of harvest planners.

expertise and training in forest mapping

Maps drawn from recent aerial photographs supply valuable information for assessing and rationally managing forest resources. In an exercise combining expert advice and training, CIRAD specialists supported local teams for preparing about 50 maps of the Gabonese forest.

The operation was carried out within the framework of the World Bank-funded project on forests and the environment. The work was subcontracted by IGN France International, a subsidiary of the French geographic institute IGN, to CIRAD, which backstopped and coordinated the work by the teams of the Gabon cartography institute, INC. Sessions on theory were conducted to supplement the hands-on training; they were also attended by staff from DIARF, the Gabonese directorate for forest inventory, management, and regeneration.

The site selected for the project was the forest located to the south of the river Gabon estuary and the scale chosen was 1:20 000, which is well suited for forest management projects. Management plans are needed both for forest conservation and rational use of forest resources. Projects for protection and renovation of the coastal forests were implemented a few years ago. The aim at present is to reduce wood exports and to promote on-site processing of okoumé wood as only 7% of the output is processed within the country. Okoumé accounts for 2 million m^3 of the total annual output of 2.7 million m^3 in Gabon.

The 250 000 ha of forest to be mapped were divided into four areas, which are characterized by diverse forest environments and types of stands. Two of the areas were located in the Sud-Estuaire region; one of them was dominated by okoumé trees and the other by primary forms. The third area had several okoumé stands that had been established in 1930 and reached full development by 1945. Accurate maps of almost 17 000 ha of okoumé plantations were drawn on the basis of aerial photographs at 1:10 000 scale. The fourth area was the reserved Mondah forest near Libreville. This area, which serves as an experimental site for the Gabonese natural resources college ENEF, has fragmented forest stands as it had been cleared for farming. Aerial photographs (at 1:15 000 scale) taken in 1995 were used to evaluate the extent of the cropped areas and establish the status of the remaining forest stands.

The techniques demonstrated and applied in the project were based on the use of standard data from infrared colour and black-and-white panchromatic aerial photographs. Low-altitude digital data and orthophotographs (digital images of aerial photographs

two international meetings on tropical forest inventory and management

In 1998, CIRAD and the Center for International Forestry Research (CIFOR) organized an international workshop on sustainable development of tropical rain forests in Africa. The workshop, which was sponsored by the French Ministry of Foreign Affairs, was held in Gabon, as part of the FORAFRI project. The researchers who attended it came mainly from central and western Africa. The discussions focused on economic and environmental trade-offs, moves to encourage participatory management, and promotion of regional cooperation for research and collection of environmental information. Another international event on monitoring forest resources was held in Jakarta, Indonesia; it was cosponsored by CIRAD and the Indonesian Ministry of Forests and Commercial Agriculture. Discussions focused on ways to capitalize on recent advances in data processing technology such as remote sensing, GIS, and ecological data management systems. Some of the main topics covered were diversity of scale, management of data from multiple sources, and mapping of biodiversity.

in which displacements by the camera and terrain are removed) were also used. Orthophotographs combine the image characteristics of aerial photographs and the geometric quality of maps.

Training was also given in techniques for validating image analysis through field observations. The use of interpretation keys for defining environmental units was also demonstrated. The keys relate mainly to cover physiognomy, stand heights, treetop shapes, and shades and levels of grey in the photographs. The parameters adopted for the legend were: characteristics of forest formations (primary, secondary, young, and adult), and characteristics of okoumé stands (location and densities).

Units coded according to the legend were then transferred from the photographs to topographical maps and digitized for incorporation in a GIS. All the resulting maps will be integrated into the regional forestry database.

trees and plantations

village seed orchards in Madagascar

In Madagascar, CIRAD and the forestry and fisheries research department of FOFIFA, the national rural development research centre, jointly conduct a breeding programme on exotic leafy tree species such as eucalyptus and acacia.

Households in Madagascar use fuelwood to meet 80–90% of their energy requirements. In some regions, most of this fuelwood, including more than 90% of that consumed in the capital city Antananarivo, is supplied by plantations.

More than 300 000 ha of plantations are reforested with exotic species because the growth rate of native species is considered too slow. The inadequate forest cover—only 12% of the total land area—has serious environmental consequences (soil erosion, irregular flow in watercourses, and river silting). Hence, the main thrust of forestry research is to participate in the expansion of plantations.

One of the objectives was to diversify and improve plant material for reforestation projects. The list of suitable species for reforestation in each region was established on the basis of research work over the past 20 years. Arboretum screening of over 700 different species revealed that *Eucalyptus* and *Pinus* species are of considerable interest because of their hardiness and quick growth potential in acidic soils. One of the main problems is that very little is known about the origins of species introduced at the beginning of the century. They probably have a very narrow genetic base as evidenced from inbreeding depression observed in certain plantations. Varieties derived from existing stands are therefore low-yielding and show morphological and agronomic drift relative to the pure species.

Annual reforestation species seed production is 300–350 kg including 150–200 kg of eucalyptus seed that is sold by SNGF, the Malagasy forest tree seed agency, which also participates in the breeding programme. But poor genetic quality of commercial seeds and high wastage due to inefficient nursery and field

techniques could seriously impede reforestation activities.

FOFIFA and CIRAD have developed a breeding strategy adapted to conditions in Madagascar (climate diversity, local resources) and to the programme objectives.

To promote reforestation in the villages, it is important to establish seed orchards for supplying seed to villagers. The use of imported parent material ensures the high genetic variability required by local conditions. The breeding programme has identified 20 different species, for which it will produce varieties that are adaptable, hardy, fast-growing particularly in the early stages, and that can be used for various purposes in different bioclimatic zones. The seed orchards thus serve as sites for conservation of genetic resources, development of new varieties, seed production, and information collection.

Between 1993 and 1998, more than 80 ha of seed orchards were planted as part of a project funded by the European Development Fund (EDF). They supplement 40 ha of trial plots previously established in collaboration with FANALAMANGA, the local reforestation company. The FOFIFA–CIRAD programme therefore manages 120 ha of seed orchards spread across a range of rainfall zones (400–3500 mm/year) and altitudes (from sea level to 1700 m) throughout the island.

The seed orchards have enabled a controlled reintroduction of genetic resources from 300 different sources for more than 20 species including eight *Eucalyptus*, five *Acacia*, two *Grevillea*, and one *Prosopis* species. This operation will make Madagascar self-sufficient in forest seeds. It is a significant achievement because a few years ago, *Acacia* seed had to be imported from Australia, which slowed down extension of plantations.

Since 1997, the seed orchards established through the joint FOFIFA–CIRAD programme have increased supply to reforestation operations. From 30 kg in 1998, seed supply is expected to increase to 100 kg in 2001.

The seed orchard project should be followed up by other initiatives, such as training programmes for nursery owners and technical support for growers, so that the entire industry can benefit from the growing number of reforestation operations. Seed orchards should also be established in other regions of Madagascar.

large-scale teak clone production

Teak *(Tectona grandis),* which originated from India, Myanmar, Thailand, and Laos, was introduced in Java, Indonesia, 500 years ago. It is currently grown over 2.5 million ha in more than 50 countries spread across Asia, Africa, and Central and Latin America. A recent meeting held in Chiangmai, Thailand, discussed the implications of the growing demand for teakwood worldwide and of the need for large quantities of improved plant material to supply the increasing number of reforestation operations.

National governments have been allocating substantial funds to breeding programmes using propagation by seeds. But as yields of viable seeds were low, innovative techniques had to be developed for mass multiplication of individuals selected for their high growth rates and wood quality. In 1989, a joint project was launched in northern Borneo between CIRAD and Innoprise Corporation, a leading Malaysian forestry company from Sabah. A noteworthy achievement of this project is the development of suitable techniques for propagation of superior teak genotypes by cuttings and by industrial-scale in-vitro culture procedures.

Simple culture media and low production costs were important concerns while developing a technique for micropropagation of juvenile and mature teak genotypes by axillary budding of 1–2 cm long microcuttings. The use of 0.3-mm meristems for introducing improved plant material reduces the risk of contamination in primary cultures and allows physiological rejuvenation of old superior genotypes. More than 90% of in-vitro

rattan in Southeast Asia

Since 1994, CIRAD conducts a rattan conservation, genetic improvement, and silviculture project in association with Malaysian research and development institutes and other organizations from the European Union.
In May 1998, an international workshop on rattan cropping was held in Kuala Lumpur, Malaysia; it was organized by CIRAD and its partners and financed by the European Union. Politicians, forestry specialists, growers, manufacturers, and retailers from eight Asian countries and representatives from international organizations attended the workshop. Apart from the scientific and research aspects, participants discussed the future of the rattan industry, whose market is valued at $6 billion/year.
In the early 1980s, a large number of initiatives had been undertaken for rattan cultivation, ranging from the kebun *(agroforestry gardens) of the Indonesian smallholders to large-scale plantations of big forestry companies.*
Despite the relatively unfavourable economic scenario, the perception of rattan as a traditional and ecological product should revive interest in the crop. Research carried out within this collaborative project has led to useful results: more accurate taxonomic classification of rattan, which includes almost 600 species; preservation of the most important species, some of which are threatened by extinction; better genetic resource management; and development of suitable silvicultural techniques for forest enrichment.

produced shoots rooted successfully in the nursery under normal horticultural conditions, and about 100 000 plantlets have been produced. Some of them were tested for conformity within the framework of the project and others were sold either as microshoots for further acclimatization or as nursery plantlets ready to be planted in the field.

As both techniques—propagation by cuttings and micropropagation—had been developed within the same project, their respective performance could be compared more effectively. The analysis revealed that micropropagation is more cost-effective and efficient for annual production levels above 100 000 plantlets. It also allows export of improved plant material without phytosanitary risks and facilitates genotype conservation. Micropropagation is useful worldwide not only for research activities but also for development of commercial plantations.

forest products

the Cameroonian wood industry

The Cameroonian government recently banned all exports of timber. The domestic wood industry therefore urgently needs to be restructured to encourage indigenous manufacturing and marketing of semifinished and finished forest products.

In late 1997, the French Directorate of Cooperation signed an agreement with CERNA, the industrial economics centre of the French engineering college Ecole nationale supérieure des mines to carry out an appraisal of the timber sector in Cameroon. The appraisal was part of a wider ranging project to assess industrial policies in Africa. CIRAD and CERNA were retained by the Cameroonian Ministry of Forestry to carry out the comprehensive assessment that would serve to orient government policy for the sector.

In 1998, Cameroon produced 2.9 million m^3 of timber, of which 1.2 million m^3 were

processed in the country. All registered sawing, peeling, and slicing mills, whether or not they were operational, were visited at 87 different sites. Interviews were conducted with each unit on the basis of a detailed questionnaire prepared by CIRAD and CERNA.

The survey focused on various aspects of the business: history, economic features, human resources, supply sources, production, equipment, energy requirements, marketing, financial information, and future plans. The technical and economic information collected during the interviews was evaluated by the experts and recorded for each unit.

The survey report and recommendations were submitted to the French Ministry of Foreign Affairs. They highlighted the major technical issues and possible improvements, as well as the advantages and drawbacks of different options.

The units were classified into three main categories. The most successful units produced for export markets and their annual production capacity often exceeded 50 000 m^3 of timber. Medium-capacity units (20 000–30 000 m^3/year) produced mainly for the domestic and regional markets. Units that exclusively supplied local markets often faced management problems that affected their performance and supply operations.

Yield—the ratio of the volume of sawn lumber to the volume of the log—was also assessed as an indicator of a unit's technical performance. The ratio depends on the characteristics and quality of the raw material, types of production, industrial capacity, processing activities, as well as management and production planning strategies. These parameters should, however, be assessed according to the particular and varied context of the wood processing industry in Cameroon. For instance, a sawing unit that makes large rough dimensions from ekki (*Lophira alata*) may have a better yield than another unit that makes small slabs from several species; however, higher yield in this case may not necessarily signify better performance.

After the survey, each step of the process was reviewed to propose improvements. Better organization and management of log yards would reduce loss of time, raw materials, and productivity. Simple methods to protect timber stocks and preventive treatments against insect pests of dry wood would improve the quality of raw material before it is processed.

The know-how of the operators and condition of the equipment are the main factors that determine productivity and breakdown yield. Professional training programmes should be included as a key component in industrialization projects.

Although Cameroon's forests offer almost 1000 tree species, only 50 are exploited and of these around 10 are reserved for export as they are highly profitable. Exploitation of new species implies the establishment of a different infrastructure (production facilities, equipment, tools) and the opening of new markets for the products. The economic options have multiple implications, which need to be carefully thought through. The technical report highlights the potential and impact of new developments in production techniques.

turnkey laboratory for wood quality assessment

A complete wood quality assessment laboratory was set up in the Republic of the Congo at the request of the UR2PI research unit for commercial plantation productivity, a national association of which CIRAD is a member. Staff was also trained in the use of the equipment. The turnkey project comprised the delivery of an automated, compact, low-cost laboratory that was immediately operational and the transfer of knowledge and know-how customized to users' requirements.

The laboratory is designed for tests of the mechanical properties of raw material to determine

machining behaviour prior to processing and remanufacturing. It can be used for all tree species, and for this project it was designed for eucalyptus. To accommodate the large number of specimens required for the tests, the laboratory was equipped with small-sized machines (circular saw, jointer-planer, plane, orbital sander, oven, and evacuation hood).

Release of growth stress needs to be estimated to determine the appearance of defects during sawing and drying (end splits during crosscutting, checks, deformation). The laboratory also has devices for assessing this parameter from measurements along the trunk circumference of residual deformation due to growth stresses.

The workbench is made up of five measuring devices—comparator, caliper gauge, digitizer, electronic scales, and rapid data acquisition board—all linked to a computer. Data collection can thus be handled by a single operator; moreover, the risk of error is nil as there is no manual scoring.

The caliper gauge measures specimen dimensions. The programmable electronic scales, equipped with a system for measuring volumetric mass relative to hydrostatic thrust, convey infra-density information. The comparator is used for measuring total shrinkage values from measurements of the specimen before and after oven drying. Total shrinkage values refer to changes from green to oven-dry conditions. The digitizer is used with a microscope for observations to determine the length and morphology of wood fibres and fibre wall thickness; these data are needed for pulp production.

The rapid data acquisition board is part of the Beam Identification by Nondestructive Grading or BING system developed by CIRAD. BING is designed for analyzing transversal and longitudinal vibrations caused by tapping the specimen (beam, panel, or pole) on the top and sides with an impactor. After measurements of dimensions and mass, the specimen is placed on two flexible supports so that it can vibrate freely. A percussion at one end of the specimen generates a wave train that is recorded by a microphone set at the opposite end of the sample and digitized through an external data acquisition board connected to the work station. The vibration mode yields different measurements: modulus of elasticity from transversal or longitudinal vibrations, shear modulus and bending modulus of elasticity from transversal vibrations.

The results are displayed alongside data taken from a reference piece without defects. Defects in the specimen are detected by comparing it with a model of the reference piece. The system is fully automated as the software

inter-African cooperation on bioenergy

Wood is also a source of renewable energy for households, and small- and large-scale industries. The promotion of this energy source in Africa requires the development of efficient, rational, and environment-friendly processes. The inter-African cooperation programme on bioenergy CIABE, which is funded by the French Ministry of Foreign Affairs, was created at the initiative of African and CIRAD researchers. It pools together the scientific and technical expertise of the partner organizations, and they share the results of their work. The activities, which are coordinated by CIRAD, currently focus on Burkina Faso, Cameroon, Côte d'Ivoire, and Senegal. The projects concern: energy production for drying of agricultural and forest products, motorization and generation of electricity in villages, exploitation of the energy potential of waste products, and supply of fuelwood to cities. The technologies could also be adopted in other regions. CIABE members trained at CIRAD subsequently train technicians and other trainers because the overall objective of this joint programme is not only to promote the use of biomass for energy, but also to strengthen African expertise in bioenergy.

delivered with BING can also read data from the electronic scales and caliper gauge.

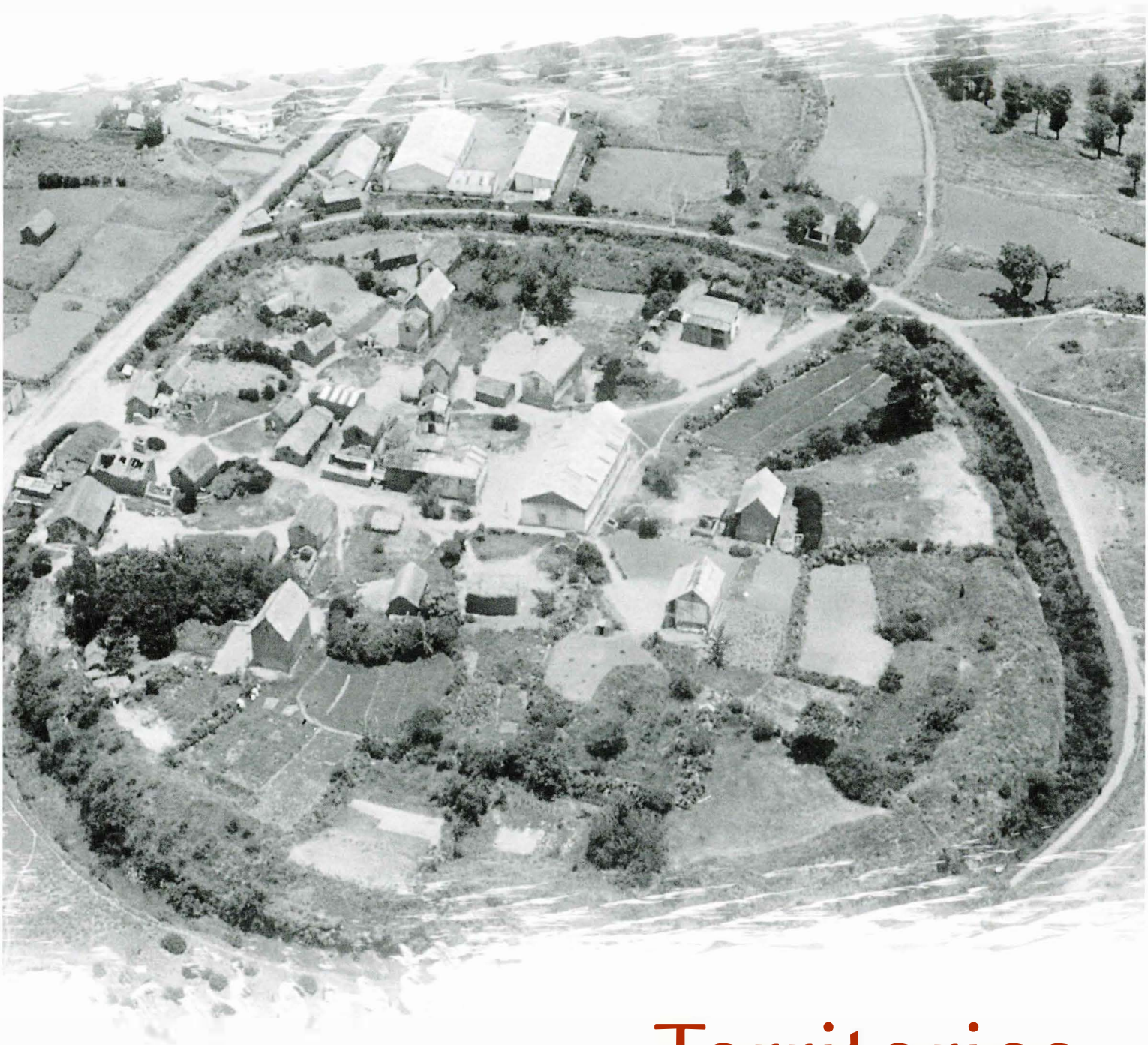
Each device fulfils a wide range of functions and can be connected to one or several instruments depending on the type of calculation. The workbench features state-of-the-art technology and serves as a useful tool for countries to improve and make optimum use of their forest products. The basic version of the laboratory can be rapidly adapted to a wide range of resources, and technical and economic situations.

With the globalization of commodity markets, the emphasis on production becomes even stronger. But production is only one of the concerns—the economic concern—of sustainable development; it has to be balanced with two other equally important concerns: social (poverty alleviation) and environmental (natural resource management). Social, cultural, and environmental issues are increasingly referred to regional bodies, farmers' organizations, and other stakeholders in rural development as a result of decentralization policies. Moreover, the stakeholders are also expected to develop economic activities to complement the main commodity sectors. They therefore need research support for identifying, implementing, and evaluating their projects. It is not an easy task given the diversity of interests and scales.

CIRAD-TERA, the Department of Territories, Environment, and People, was created in January 1998 in response to the need to contribute to these projects through studies of human activities in their spatial context and through research to support regional development. The Department's research focuses on three key themes: diagnosis and graphic display of regional situations, mechanisms for individual and collective decision making, and management of resources and means of production.

Methods and tools are developed within two programmes: Family Agriculture Programme and Land and Resources Programme. They are designed for diagnosis and display of information (eg, models, GIS), decision making, support services for development, management of resources and inputs, impact assessment, and evaluation. These methods and tools are used by regional development programmes and by those working in the different commodity sectors.

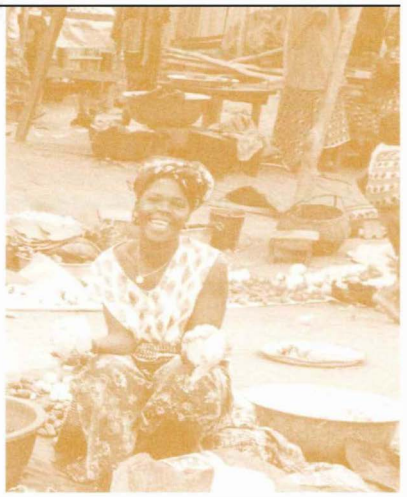
The two other programmes—Savannah and Irrigated Systems Programme and Humid and Insular Tropics Programme—fulfil a coordination function for their respective regions by working together with local partners to propose research-based solutions. The programmes operate within the framework of regional projects and local operation networks.



Territories, Environment, and People

family agriculture

farmer trials in Central America



Over the past decade in Central America, farmer trials are increasingly integrated in participatory research thanks to the efforts of nongovernmental organizations. Farmers are no longer regarded simply as vectors of information, but also as a source of knowledge and advice.

Since 1993, this approach has been developed as part of PRIAG, a technical cooperation programme involving the European Union and six Central American countries; its aim is to strengthen food crop research. CIRAD and the Dutch tropical research institute, KIT, provided technical support for the programme. Over the past 5 years, researchers and extension agents have assisted informal groups of nearly 600 farmers in conducting their own trials. The trials covered a wide range of operations: soil conservation, organic fertilizer application, variety comparison, cultivation, and postharvest processing. The resulting innovations in methodology and organization were implemented in several countries for participatory planning, training courses, exchanges between farmers from different countries, and the creation of local research structures. This operation demonstrated the importance of reorienting research on the basis of feedback from farmers. It also highlighted the capacity of development workers to support farmers' initiatives.

Farmer trials should now be extended to other regions. Research teams in Costa Rica and Panama plan to integrate the PRIAG innovations into their programmes. Some NGOs in Nicaragua and El Salvador already apply them. The experience was also shared with operators in other Latin American countries and Madagascar.

regional diagnosis for New Caledonia

In 1998, elected representatives from the Nord province of New Caledonia commissioned a diagnosis of rural development in their province. The mandate was to review the situation in the rural areas 10 years after the French central government signed the Accords de Matignon on the status of the overseas territory. Based on the findings, the authorities had to define a 5-year research programme for regional development. For this project, the Department worked with the directorate of fisheries and rural development, DDRP, and with livestock and veterinary medicine specialists from CIRAD.

The diagnosis showed a decline in commercial agricultural production in the province. Considerable variation was observed in agricultural conditions as well as a high level of off-farm activity as farmers often took up temporary unskilled jobs. Support to farmers should therefore take all these enterprises into account. The diagnosis showed the limitations of linking government aid to volume of production for developing the different crop sectors. The burgeoning of associations and rural development initiatives was evidence of the dynamism of the different social groups; these movements should receive more support from development organizations.

At the first presentation of findings in October 1998, the Department was able to test the acceptability of its proposals. The meeting with DDRP officials was held in their territory, where the Department was

able to observe the specific constraints they face. The final presentation is scheduled in early 1999, before the contracts for development funding are signed between the French government and the Nord province authorities.

A regional development programme was also established for the longer term. In 1999, training courses will be held on methods of local development and rural management based on an overall approach to agricultural enterprises. An agricultural economist will join the CIRAD team in early 1999.

A socioeconomic observatory is also planned for monitoring and evaluating development operations in real time.

workshop on family agriculture

The Family Agriculture Programme organized an international workshop on 2 and 3 February 1998 to critically review the main strategies of the Programme. In their presentations, specialists from CIRAD and other organizations discussed the diversity of socioeconomic situations facing farmers in the context of globalization. In the final session, after validating the strategies selected for their relevance to research issues, the participants further developed the structure and content of these strategies. Thus, it was decided that the Programme's activities should be based on stakeholder strategies and decision making; agriculture-related organizations, institutions, and services; and value addition for agricultural products and local development.

land and resources

agriculture in the Eastern Cape in South Africa

In the former bantustan Ciskei, now part of the Eastern Cape province, the extremely small size of the farms makes it difficult to integrate them into the market economy. The Agricultural Research Council (ARC), South Africa, sought assistance from CIRAD and the French agricultural research institute, INRA, for finding a solution, which would also resolve certain social problems. Project Umthiza was thus launched with funds from the French Embassy in South Africa. Umthiza is the name of a research station, which will be later developed as a research, development, and training centre for family agriculture.

A diagnosis of the diversity of the rural households was carried out in 1997. The results were discussed at a seminar organized by ARC and the Universities of Fort Hare and Pretoria. The main problems were an ageing farmer population, unemployment (40%), low agricultural productivity, and inefficient production techniques. As most land was collectively owned with rights of use, there was considerable pressure on natural resources. With the exception of a few large landholdings, privately-owned plots were limited to gardens of 1000–3000 m².

The diversity of situations, the reasons behind farmers' choices, and their food needs had to be understood for defining the conditions for establishing a true family agriculture system.

renewable resource management in Senegal

For the fifth consecutive year, the French Ministry of Foreign Affairs commissioned CIRAD to conduct a training programme on renewable resource management. This time the programme was organized in Africa. It was held at the Senegalese institute for agricultural research, ISRA, in Saint-Louis, Senegal, from 16 to 21 November 1998. The course was attended by 17 participants. The approaches developed by CIRAD, such as multiagent simulation and patrimonial mediation for collectively owned resources, were demonstrated. To illustrate their use in development projects, the trainers also presented various case studies, such as the coordination of different land uses on the periphery of the Djoudj bird sanctuary, planning of land use and allocation in a rural community in the river Senegal delta, and management of the river's irrigation systems. Through the use of role play, the participants were placed in negotiation situations created by group dynamics, similar to those occurring for the management of common resources.

In 1998, three studies were conducted after the area had been zoned by experts. They focused on land management in the village; cattle production techniques (the cause for soil erosion on common land); and modes of consumption, processing, and marketing of food products.

The methodology (zoning techniques, development of typology, and collection of technical and economic data) generated interest, and a post for a professor was created at the University of Pretoria. It is held by a CIRAD researcher, who has the responsibility of advising on tools for systems analysis, and research and development. In addition, several CIRAD researchers attended the symposium on "Farming Systems Research and Extension" (Pretoria, 30 November–4 December 1998), when they had the opportunity to interact with various actors involved in rural development.

soil fertility in Africa south of the Sahara

People living south of the Sahara will continue to suffer chronic food shortages if soil fertility in cultivated areas is not improved significantly. Farmers' choices regarding cropping practices and fertility management depend on a number of economic, social, and cultural parameters. These must be understood so that suitable solutions can be found for each small farming region.

The World Bank's Soil Fertility Initiative for Africa south of the Sahara aims to coordinate the work conducted in this area. The Initiative is undertaken in collaboration with regional research organizations (CORAF, ASARECA, and SACCAR). CIRAD is involved in this Initiative in Burkina Faso, Côte d'Ivoire, Ethiopia, Guinea, Madagascar, Mali, Niger, and Senegal through an FAO technical cooperation programme. In each of these countries, diagnoses were carried out jointly with CIRAD's Annual Crops Department.

Pressure on land, resource extraction, low returns, and unstable markets all lead to varying degrees of soil degradation. Many technical solutions are not adopted by farmers as they see no direct benefit or because the inputs and equipment are not available. Private sector initiatives for distributing fertilizer and soil additives are hampered by regulatory problems, inadequate infrastructure, lack of foreign exchange, and an inefficient banking sector.

To address these problems in each country, CIRAD's researchers worked with all stakeholders concerned to prepare national action plans to improve soil fertility. The first steps include experiments for improving soil organic matter content and reducing losses due to runoff. Pilot operations are also planned for input supply involving private agents, public authorities, and farmers' organizations.

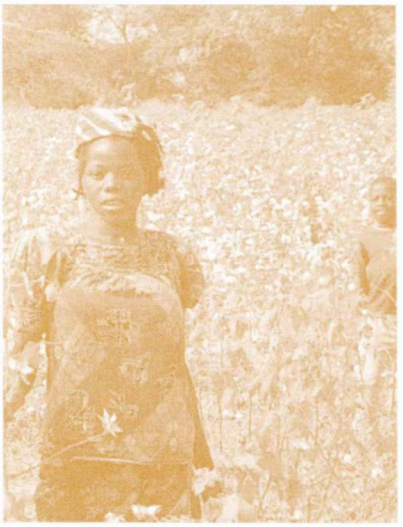
savannah and irrigated systems

development of the shallot industry in Mali

In Mali, the devaluation of the CFA franc stimulated horticulture crop production in the irrigated areas, which supply markets in Bamako, Mali, and in Abidjan, Côte d'Ivoire. Potato production developed in the *bas-fonds* (inland valleys). In the Office du Niger command area, shallot production reached 70 000 t over 2600 ha; it now accounts for 40% of national production. Shallot, which is traditionally cultivated by women and children, represents 30–40% of farmers' incomes. But prices are low when it is harvested in March or April; whereas in September it would fetch five or six times the price.

A research and action operation was launched by researchers from the URDOC observatory of changes, conducted jointly by the Office du Niger and CIRAD, to address the problems of shallot conservation, quality, and marketing.

In 1994, they designed a storehouse with improved aeration, protection against insect pests, and storage capacity. The storehouse was the starting point for a dialogue between researchers, producers, and retailers that has led to gradual structuring of the sector.



Mali's rural economics institute, IER, was responsible for characterizing varieties and their keeping qualities; masons were trained to build the storehouses; drying and postharvest processing trials were conducted; women's groups were given loans for the off-season; and business groups were set up to market shallots in Bamako. To keep producers informed of production prices and statistics, spot market prices are broadcast on the local radio each week in addition to other programmes that give technical advice.

These actions to support the local shallot industry were undertaken in partnership with the World Bank project implemented by the Mali-based APROFA agency for promoting commodity sectors.

Links were established with the Dogon region, Mali's other shallot-producing zone. Prices have shown stability over the past 2–3 years. In the next stage, the chamber of agriculture, which was set up in 1996, will gradually take over some of the support functions. URDOC thus helps farmers and their organizations become more autonomous.

local planning in the river Senegal valley

In Senegal, responsibility of local management has now devolved from the central government to the locally elected authorities. Their land use and allocation plans serve as guidelines for designing and implementing development projects. Paradoxically, they have no cartographic tools, planning guidelines, or institutional support to carry out their tasks.

In 1994, the public development corporation, SAED, supported by CIRAD, had developed a geographic information system for monitoring and developing irrigated agriculture in the river Senegal valley.

In 1997, the system was used in a pilot operation to draw up plans for land use and allocation. One of the requirements of this decentralization experiment was that it should be operational from the outset and at a cost not exceeding the local budget. The

test was carried out in a rural community of 50 000 inhabitants in 315 villages, spread over 2500 km². Priority was given to building institutional capacity so that the work can be carried out without external assistance in future. The capacities of the rural councils—the basic administrative entities—were strengthened. Regional and national institutions were mobilized to provide the necessary support. Maps were drawn up with the help of technical services and then amended and validated by the local communities at workshops organized and coordinated by the rural councils. Land-use regulations are now formulated autonomously by the rural council, in consultation with the inhabitants. The system is now operational and involves relatively little external assistance.

In 1999, the aim is to extend this decentralized planning exercise to the regional level. The object is to promote regional development from the grassroots, by gradually building up institutions starting from rural organizations up to regional bodies.

evaluation of the regional research pole for irrigated systems

The regional research pole for Soudano-Sahelian irrigated systems, PSI, involves the national research centres of Mali, Mauritania, Niger, and Senegal (IER, CNRADA, INRAN, ISRA); it is coordinated through the CORAF network, in partnership with CIRAD and the French research for development institute, IRD. The activities of the research pole were reviewed in 1998. It was recognized as a unique regional initiative for coordinating the activities of national programmes. Knowledge acquired on soil degradation in irrigated areas can now be used for testing solutions. Tools for negotiations and discussions on the functioning of irrigation systems were tested through users' associations. Different possibilities were identified for crop diversification. The review recommended that work on intensive rice cultivation should take into account the overall farming systems. It also recommended that regional coordination and links with development operators be strengthened.
The first phase of the activities of the research pole will be completed in December 1999, and a workshop will be held in Dakar, Senegal, to discuss the results.

humid and insular tropics

French research in the Amazon basin: appraisal and prospects

A conference on French cooperative research in the Amazon basin was organized in Montpellier, from 30 November to 1 December 1998, on the initiative of the French Ministry of Foreign Affairs, CIRAD, and two other French research organizations, IRD and CNRS. It was attended by 150 Brazilian, Venezuelan, and French researchers to evaluate past work and to discuss new collaborative projects. Discussions focused on the evolution of natural habitats, development of renewable resources, and the economic and political conditions conducive to sustainable development.

Participants stressed the significance of the environmental diversity of this vast region and its rapid transformation. Research results obtained so far do not cover this diversity and the technical reference datasets are still incomplete. Priority should be given to the assessment of the

impact of human activities. Research should focus on the development of farming systems that make optimum use of the region's environmental diversity. Little work has been done on the overall economic situation and sectoral policies, despite their crucial influence on the advance of pioneer fronts. Land tenure, organization of commodity sectors and their markets, urbanization and food supply to towns, and migration were proposed as important research themes.

The Brazilian institutions stressed the need for a local research capacity in the Amazon region, as it would be in a better position to respond to the actual needs of the local communities and to develop research oriented towards regional development.

These issues will be addressed within the framework of the cooperative agreement with the Amazon basin secretariat of the Brazilian Ministry of the Environment. The agreement covers impact assessment of different land uses and an appraisal of regional development. These priorities will also be covered by interinstitutional activities that the conference participants decided to undertake together.

CIRAD-AMIS, the Department of Advanced Methods for Innovation in Science was created on 1 January 1998 by bringing together researchers from different disciplines. Certain programmes of the Department are a continuation of ongoing work, whilst others were developed from new synergies. The thrust of all programmes is to design and adapt the tools, methods, and models that are necessary for CIRAD to fulfil its mandate, in close collaboration with the national and international scientific community. The programme teams of the department thus focus on designing generic, cross-cutting methods, whose applications are further developed through the activities of CIRAD's commodity programmes. Another task for the programme teams is to make available the knowledge and methods they have accumulated over the years to external researchers who are trained in their laboratories.

During this first year of activity, the Department concentrated on organizing its teams and laboratories, developing joint research projects, and establishing partnerships with research teams in Brazil, China, Colombia, Indonesia, Senegal, and Thailand. Links were also developed with universities to build mixed research teams particularly for doctoral studies and to host doctoral students working on research topics relevant to the development of Southern countries.

Some of the Department's researchers—in Nogent-sur-Marne, Montpellier, and Réunion—work on national scientific research projects. The Génoplante project, which was undertaken in 1998, is noteworthy in that it brings together research teams from the public and private sectors. Their task is to inventory the cereal gene pool, patent the results, and guarantee their accessibility for both the South and North.

The Department's researchers aim at excellence in quality control and safety in research methods through ISO certification and quality assurance. They strengthen this endeavour through training of research partners on these aspects.

Through its work with corporate partners in the North and South who use its services, the Department is actively involved in information exchange and the validation of technical innovations according to users' specifications.

Advanced Methods for Innovation in Science

agrifood systems

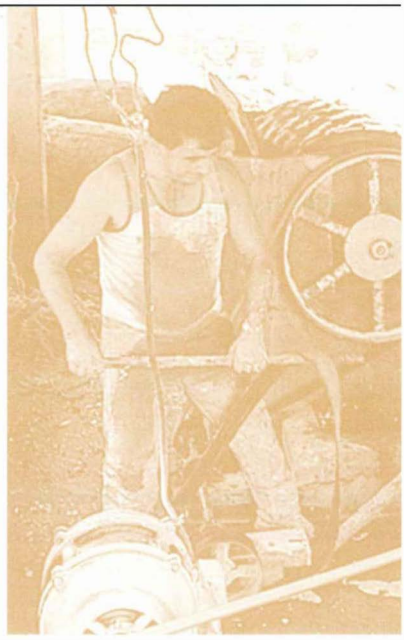
improving the quality of local products for the urban market

Many research projects and enterprise start-ups in the agrifood sector in Africa are based on the hypothesis that the urban consumer prefers consistent quality, standards, hygiene, proper presentation, and ease of use. However, supply of local processed foods is dominated by small and micro enterprises, whose products are often of poor quality.

To test this hypothesis, CIRAD carried out consumer surveys in several cities with various partners—ENDA-GRAF, IRIS, and ITA in Senegal; CNRST and the University of Ouagadougou in Burkina Faso; CERNA in Benin; CRBP in Cameroon; and ARC and ARDRI in South Africa. The main purpose of the surveys was to determine what city dwellers expected in terms of product quality and how they checked it.

Product quality is an amalgam of several aspects such as organoleptic characteristics (taste, smell, texture), territorial specificity (linked to indigenous know-how), health and hygiene, and ease of use.

The relative importance given to these different quality criteria varies primarily with the product.



For some products, consumers do not seek standardization because it would wipe out the existing variety of traditionally-prepared foodstuffs. Consumers want variety, given the diversity of their cultural backgrounds and dietary customs. They are firmly attached to local products, especially to those foods with a strong cultural connotation. In towns in Benin, consumers can choose from a range of *gari* (ground cassava) from different regions. The same is true in Ouagadougou for *soumbala* (a fermented condiment) and *dolo* (a beer from red sorghum).

Hygiene is a matter of concern to urban consumers only in the case of certain products, particularly those prepared by traditional producers whom the consumers regard as "nonprofessional". In urban situations, consumers cannot check the working conditions of an enterprise nor assess the extent to which it respects hygiene standards. They rely on their relation of trust with their suppliers and usually attach little importance to official certificates of cleanliness. A product is finally accepted only when the vendor has won the customer's confidence.

The ease of use of a product is less important for the consumer than might be expected. Certain laborious processing operations are not seen as chores because the task is simplified by the large number of people in most households. Other operations are seldom delegated to others, especially when they increase the social status of the housewife. In many towns, the purchase of certain industrial foodstuffs is regarded as demeaning. However, housewives accept mechanization when they produce for resale since they can monitor quality throughout the process.

The perception of quality by consumers depends also on the use of the product. In Ouagadougou, for example, maize is preferred to sorghum for preparing *tô* even if it is less nutritious, because maize paste is whiter and keeps longer. Quality criteria for the same

dish and ingredients can vary with the type of meal: everyday or festive, midday or evening. There are no absolute measures for quality; it is not inherent to a given product.

Health, nutritional, and organoleptic characteristics are more difficult to discern. The large number of suppliers and lack of standardization in product composition and processing further complicate the task. Customers thus use other methods to judge product quality.

A typology of these methods was established on the basis of the survey results. It distinguishes broadly between direct sensory assessment (sight, touch, smell, taste) and indirect methods (degree of confidence in the vendor, price, certification, and reputation of the product or producer). Within these categories there is further differentiation according to products, consumers, and situations in which the products are used.

A product launch or product upgrade should not be based on purely technical considerations. Although improvement of the quality of local products for urban markets may be a relevant goal for research work or for starting a business, the quality criteria applied by consumers and the price they are willing to pay for such improvements should be studied on a case-by-case basis.

The simple rapid appraisal methods developed by CIRAD can be used to assess the socio-economic and commercial relevance of these criteria. These analyses also place the technical aspects, organizational rules, and institutional facilities for product quality improvement in a new perspective.

designing small-scale equipment

New markets can be created for agricultural products from the South through local food processing. At present, however, users in these countries lack the equipment suited to their limited budgets. CIRAD therefore launched a research programme in 1996, with the specific objective of strengthening capacity for the design of small-scale equipment for local development and manufacture.

The first phase of the programme focused on a historical analysis of the design and dissemination of certain types of equipment in the Southern countries. It was carried out in partnership with local teams of teachers, researchers, and equipment manufacturers in Colombia, Côte d'Ivoire, Senegal, Tunisia, and Vietnam. A detailed analysis of the different steps of the design process highlighted the factors that favoured, or hindered, the marketability of the proposed equipment. A multidimensional matrix model was thus prepared of the traditional equipment design procedure.

Representatives of the different teams then met to propose a

the total quality management school

Total quality management (TQM) is a business management concept that is increasingly adopted across all sectors. It is based on two principles: anticipating customer requirements to ensure customer satisfaction and involvement of staff in all stages of the activity. TQM reduces production costs and lead time, increases the company's competitiveness, and enhances its corporate image. TQM is based on simple methods and well-defined tools that are applied at different levels: quality control, quality assurance, accreditation, and certification for national and international norms. The quality management college ESIMAQ was recently established in Casablanca, Morocco, at the initiative of Moroccan industrialists and several French and international organizations, including CIRAD, the French engineering school ENSAM, and the foundation for innovation and industrial research in Europe IRIE. ESIMAQ offers courses for both professional studies and continuing education. The director of the college is a CIRAD researcher.

design methodology that was suited to socioeconomic conditions in the South and that defined the steps and prerequisites for a successful design programme. The CESAM method is the result of this work. It provides a detailed framework to help equipment design teams implement their projects. The method is based on a multidisciplinary approach and an analysis of users' requirements. It orients designers to consider, right from the outset, the manufacturing and maintenance elements of the equipment. Its simultaneous engineering approach allows effective information transfer between the different design functions and an evaluation of progress in relation to decision making and information availability. CESAM enables effective project monitoring and integrates the new notion of quality in design. The CESAM methodology is undergoing validation in actual equipment design projects in Colombia, India, and Senegal. CIRAD provides methodological support to local teams through training and advice on the organization of the design procedure.

The Department also plans to produce a designer's guide for design teams and manufacturers in the South.

agronomy

study of soil fertility trends in the irrigated areas of Mali

In Mali, of the 200 000 ha of irrigated lands, 65 000 ha have been developed by the river Niger development organization Office du Niger. Rice yields have risen over the past decade and now exceed 5 t/ha for the first crop of the year. However, after more than 50 years of cultivation, the lands are now showing symptoms of soil degradation linked to alkalinity and sodicity.

The Malian rural economics institute IER and CIRAD undertook an international survey—through the regional research pole for Soudano-Sahelian irrigated systems (PSI) in which they participate—to ascertain the nature of the problem and its risks. The survey aims to characterize the phenomenon and its likely evolution, and to assess its impact on crop production.

Salt concentration and distribution in the soil appear to be primarily linked to water dynamics induced by irrigation and drainage. They were studied at different levels: command area (salt and water balances); irrigation system (water table dynamics and soil variability); and rice field (irrigation treatment management). These studies were supplemented by a modelling of solute flows in the soil profile.

Drainage management had been inadequate before the irrigated systems were rehabilitated during the 1980s. Alkalinity and sodicity increased in the less permeable clayey soils. Leaching occurred

in the highly permeable sandy soils, where the water table rose from a depth of 42 m almost up to the soil surface.

Improved irrigation and drainage management in the rehabilitation areas led to the development of off-season crops. However, upward capillary movement of water caused salt concentration in the upper soil horizons. Alkalinity and sodicity increased in sandy soils, although they remained stable, or decreased, in clayey soils.

Low drainage during the off-season led to a surplus salt balance. When irrigation was resumed during the rice cropping season, large quantities of salt were discharged into the drainage system through flushing. At higher altitudes, soil alkalinity and sodicity increased because leaching was reduced due to inadequate irrigation management.

Although groundwater drainage had little effect, the salt balance was in deficit during the cropping season, but otherwise close to equilibrium throughout the year.

The conditions that lead to soil degradation could thus be identified from the survey findings. The data and parameters were also used for modelling hydro-geochemical changes in the soil profile under both cropping and irrigation conditions. The models described different processes: water and solute transport in irrigated rice fields, geochemical mechanisms of alkalinity, and physical soil degradation due to sodicity.

To link the models, the Department worked with the French agricultural research institute INRA and other research centres. Deterioration of the hydrodynamic properties of soils due to sodicity was evaluated at the IER laboratory in Niono. The equilibrium and kinetics of the geochemical mechanisms of precipitation and dissolution of minerals, and of cationic exchanges were measured by CIRAD. With the assistance of the French research organization IRD, cores of undisturbed soil were taken for a simulation of soil behaviour in a controlled environment. Water and chemical behaviour of cropped soils was also monitored in Mali during the 1998 season.

Parallel field and laboratory studies were conducted of various mechanisms such as the increase in partial pressure of CO_2 and decrease in pH, as well as their causes and consequences.

The findings will be used to enhance, adjust, and validate the model in 1999. However, it is already clear that soil degradation has only a marginal impact on irrigated rice crops, whereas 20% of the area under horticultural crops is affected.

The tools and methods developed for these studies conducted at different scales can also be applied under other soil conditions, volumes of irrigation water, and cropping conditions. In this way, they can be used for characterizing the expected effects of irrigation on the physicochemical properties of soils to ultimately determine changes in their fertility.

analysis of yield variability in smallholdings

High yield variability is a typical problem in the agricultural landscapes of the Soudano-Sahelian zone. In western Burkina Faso, data were collected from 450 maize plots in farmers' fields to analyze yield variability and to develop an innovative yield component model.

The model studies the different components of maize yields: number of fertile maize plants, number of ears per plant, number of grains per ear, and grain weight. The levels for each component were recorded for different phases: vegetative, floral initiation–flowering, flowering–seed abortion, and grain filling–maturation.

The levels recorded at each phase for the different components indicate crop performance at a given time. The maximum possible value for each component in a given agroclimatic zone will depend on the cultivar,

ISO norms for CIRAD's quality control laboratory

In keeping with the changes in regulations for better and stricter quality control, CIRAD's physicochemical analysis laboratory is organizing its quality assurance system to meet the ISO 9002 norm requirements. This restructuring involves revision of general and operational procedures, drafting of instruction manuals for use and verification of analytical equipment, and standardization and maintenance of laboratory logbooks.
All of these documents will be evaluated by a certification committee in 1999. ISO 9002 certification will guarantee the quality of services provided by the laboratory and will consolidate CIRAD's expertise in the management of quality control laboratories.

levels reached by previous components, and degree of competition between plants encountered by the developing component. The plant density threshold calculated from these parameters is a limit beyond which plants compete for access to resources (water, light, minerals).

For each maize variety, optimum yield increases with plant density up to the lowest competition limit, it then levels out, given the compensation effect of successive components. Optimum yield starts to decline when plant density starts restricting the frequency of fertile plants. Maximum yields are obtained with the lowest densities for optimum yields combined with the best compensation effect between the yield components. These are the densities that farmers opt for most frequently.

The model developed by CIRAD calculates, at the end of each phase, the optimum yield that can still be achieved if the rest of the crop cycle continues without stress. Yield potential indices can then be calculated for each phase. The effect of general conditions can be separated from that of site-specific conditions (rainfall, topography, soil, technical, and pest factors). Indices for different cultivars can be compared once the yield limit and optimum level are known for the different cultivars.

The indices represent the site-specific conditions, including stress, that influence the development of a given phase of the crop cycle. The most limiting crop phase can thus be identified from the overall representation of the cropping conditions based on the indices.

A multivariate analysis of different stress profiles indicates the most limiting phase or phases and identifies situations where a stress can become permanent. In the test sample, the stresses were linked more to cultivation techniques than to environmental factors.

The same indices also served to develop an objective method for mapping site-specific stress in the cycle. A particularly severe stress during a phase of the cycle corresponds to an index value that is much lower than others. In the situations studied in Burkina Faso, flowering was the phase most affected by stress.

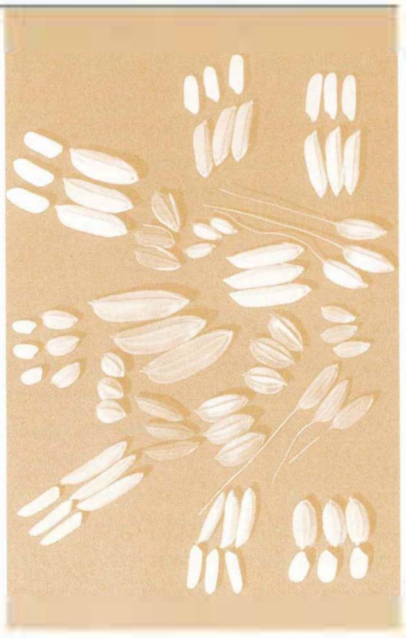
The tools developed to analyze maize yield in tropical areas are more effective for interpreting survey data sets than empirical statistical equations. In the case of western Burkina Faso, the combining of agronomic data, knowledge of varietal characteristics, and socioeconomic information on smallholdings enables a better understanding of farmers' strategies. This type of analysis suggests new approaches for research and development organizations.

plant biotechnologies and genetic resources

genetic diversity of Criollo cocoa

The Criollo cocoas from Central America and the northern part of South America are widely appreciated for their aromatic quality, particularly by chocolate producers.

CIRAD therefore seeks to gain a better understanding of the domestication of this group. In collaboration with the Venezuelan centre for agricultural research, CONICIT, it undertook a study of the genetic diversity of the group. Analyses based on RFLP (restriction fragment length polymorphism) markers and microsatellites were carried out on Criollo samples collected in Mexico (particularly near Maya sites in the forest of Lacandona and in Yucatán), Colombia, Guatemala, and Nicaragua.



Preliminary results reveal the hybrid nature of most Criollos grown in these areas and a genetic similarity to Trinitario, a hybrid group between Criollo and another group of cocoas, the Forastero group. "Pure" Criollos, the direct descendants of the first cacao trees cultivated by the Mayas, were found in the Lacandona forest and in Yucatán. Despite a certain morphological variability in pod shape, the pure Criollos, like those in old plantations in Venezuela, show strong genetic similarities and correspond to homozygous genotypes for 95% of their genome. Pure Criollos therefore have a very narrow genetic base and probably represent an ancestral form of the existing Criollo and Trinitario hybrid populations.

RFLP data and microsatellite analyses of about 20 Trinitarios also indicate that the Forasteros, which gave the Trinitario and Criollo hybrid populations, also have a very narrow genetic base. They are probably related to the Matina variety from the lower Amazonian basin; but this result still needs to be confirmed on a larger hybrid sampling.

The variability in the Criollo and Trinitario populations is probably mainly due to variations in the genome structure, where different parts of the genome exhibit different degrees of hybridity. As this population has developed only over a few generations, the associations between markers and neighbouring useful genes have probably been conserved on the genomes. It should therefore be possible to identify markers that are linked to the genes controlling aromatic qualities in the Criollos. The markers will facilitate early selection and use of Criollo and Trinitario germplasm.

somatic embryogenesis of banana and coffee

Somatic embryogenesis is currently regarded as the most efficient technique for cloning crop species. However, several difficulties have delayed wide application of this technique and discouraged both investors and decision makers from supporting it. The difficulties are linked to the transfer of this technology from research to industrial scale, its production costs, and somaclonal variations in the material. For many species, in-vitro culturing of cells can lead to a wide range of variations in regenerated plants.

CIRAD has nevetheless pursued its research on somatic embryogenesis. Technical innovations combined with a more pragmatic

quantitative trait loci for sorghum and maize

Grain quality is an increasingly important criterion for cereal variety improvement. Together with the French company Rustica-Prograin and the agricultural research institute of Burkina Faso INERA, CIRAD undertook a research programme on the genetic factors involved in the technological quality of maize and sorghum grain.
Quantitative trait loci (QTLs) are portions of the genome that code for quantitative characters. Detection of the QTLs for grain quality can lead to the development of new improvement strategies, particularly marker-assisted selection, that can be used for combining production and quality traits.
For maize and sorghum, QTLs of four technological characters—grain hardness, and contents of amylose, total proteins, and lipids—were identified. Grain quality QTLs specific to sorghum, such as dehulling yield and vitreousness, were also detected. In both crops, the QTLs controlling total proteins content were found to be associated with those for physical characters of the grain (hardness, dehulling yield, and vitreousness in the case of sorghum). Many of these QTLs could be linked with known genes or previously identified QTLs.

approach to the problems and a progressive validation of the process could soon result in industrial applications for micropropagation of banana and coffee plants. The work has been carried out in partnership with Vitropic, CIRAD's subsidiary for marketing plantlets, and CATIE, the regional centre for agricultural research in Costa Rica.

There is already a demand for quality plantation material for these two crops, and it will grow with the availability of improved plant material (hybrids, new varieties).

Despite differences between the two species in biological, agronomic, and economic constraints, similar micropropagation strategies (succession of liquid and solid phases, hormonal and nutritional balances) can be used for them.

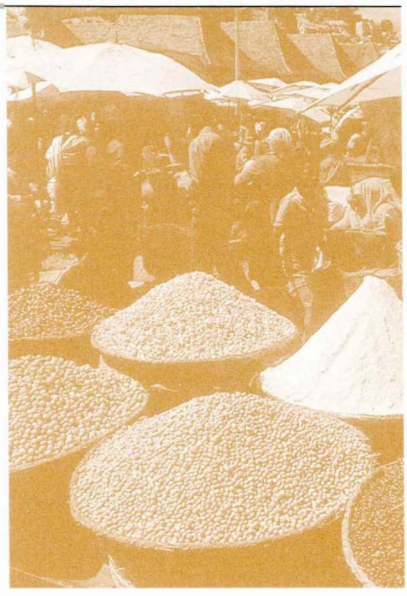
More reliable processes have been developed to reduce the cost price of plant material. In one process the cells are cultured in a liquid medium and grown in vitro for a short period; this produces sufficiently strong plantlets for acclimatization. Cost reduction is a determining factor for coffee, given the high plantation densities and low price of *Coffea arabica* seeds.

Techniques have been developed for cryopreservation and for controlling agronomic characteristics of micropropagated plant material to minimize the risk of disseminating somaclonal variants. They guarantee the quality of plants supplied to users. New molecular tools for characterization of variant plants facilitate detection of abnormalities. Nonetheless, micropropagation processes need to be validated through increasing scale field experiments.

These are the first species, after conifers, for which micropropagation through somatic embryogenesis will soon be possible on a commercial scale.

CIRAD's know-how makes it a world leader in this field. It will use this knowledge to define strategies that can be adapted to different crop species. Work on cocoa, coconut, rubber, and oil palm is under way in collaboration with other research teams.

strengthening African expertise in agricultural policies



Countries in Africa are on the learning curve for negotiating and supporting economic liberalization and privatization. CIRAD's work to strengthen local expertise involves the development of instruments for sectoral analysis and training in formulation of agricultural policies. The work is carried out in partnership with many organizations involved in research and teaching, including INRA, ENSAM, and the University of Montpellier I (France); CIRES (Côte d'Ivoire); IER (Mali); and LARES (Benin). Several initiatives were taken in this area during 1998.

Since the beginning, economic analysis has sought to show that the market is the best regulator of the economy. However, the experience of 15 years of structural adjustment in developing countries has shown the limits of the market approach, a fact supported by many theoretical works.

In terms of resource allocation and welfare of the people, better results can be achieved through other forms of economic coordination such as the hierarchy of private enterprise, voluntary involvement of those concerned, and public bodies. Among current theories, that of institutional analysis in particular provides the means to identify the most appropriate way to organize these forms of coordination.

Many theoretical and empirical works on neoinstitutional economics have been produced in recent years, but noticeably few methodological documents exist on the subject. Following an initiative by the FAO, CIRAD is preparing a guide for decision makers in African ministries. It will outline the different theories for analyzing agricultural sectors and will clarify the concepts and instruments of institutional analysis for defining support measures in liberalization polcies.

A network focusing on cocoa policies was established in collaboration with Oxford Policy Management (OPM), United Kingdom, and with the support of the French and British ministries in charge of cooperation. The network will conduct a comparative analysis of the liberalization policies of several countries. A seminar on analytical tools will be held with the aim of enhancing and harmonizing

institutional change and agriculture

In most developing countries, structural adjustment and liberalization policies have brought about profound institutional changes in the agricultural sector. Economic liberalization and the privatization of entire agricultural sectors have led to institutional reforms and thrust agriculture into the market economy.
The process of transition from a subsistence and largely government-controlled economy to a market economy should be carefully managed. Should the approach be one of confrontation between public options and market forces or one of complementarity and interaction? These were some of the questions discussed at a seminar organized by the FAO and CIRAD in Rome in October 1996. The proceedings of the seminar, Institutional Changes for Sustainable Agricultural and Rural Development, *were published in 1998.*

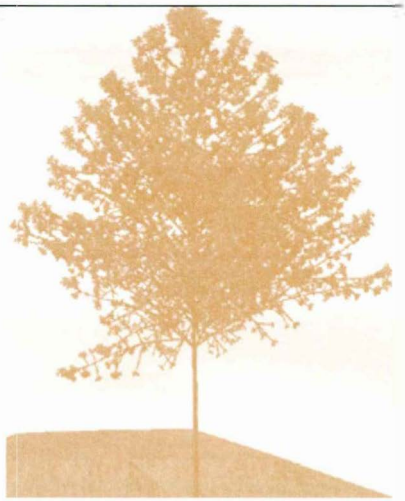
the methods used by the western African members of the network.

At the initiative of the French ministry in charge of cooperation, a regional centre for agricultural policy training was established for government officials. The workshop held in Dakar, Senegal, in October 1998 served to clarify the content and methods of the centre, to identify African resource people, and to prepare two pilot activities. One activity focuses on the national nodes of the regional observatory on cattle and meat markets, the other is intended for senior civil servants responsible for developing food security policies in Guinea.

Despite certain difficulties, there is a growing awareness of the need to move beyond the current practice of cooperation through secondment of foreign experts and to build African expertise in agricultural policy making.

plant modelling

using scans to model the internal structure of tree trunks



Advances in computer and sensor technology now allow nondestructive observation of the internal structure of biological entities for obtaining detailed information. Applications in forestry enable measurement of mechanical properties of wood and rapid diagnosis of defects and abnormalities.

CIRAD's expertise in computer graphics and image analysis and synthesis were valuable assets for a project to assess wood quality and to simulate machining behaviour of wood during sawing. The project is financed by the European Union and involves organizations and universities specializing in wood research including INRA and CTBA, France; University of Freibourg, Germany; University of Luleå, Sweden; and VTT, Finland.

CIRAD has developed a software platform known as C2000 that combines a range of generic methods—description, measuring, modelling, simulation, and tracking of changes in volume—and operating system tools. The C2000 software can be customized to meet specific users' needs. CIRAD has also designed tools for segmenting three-dimensional images from X-ray scans so that specific entities can be extracted. With these tools, it has been possible to automatically detect different components of the trunk (pith, growth rings, and knots) in scanographs of spruce logs.

The results of this analysis are matched with wood quality forecasting models developed by INRA and then validated on sawn log sections.

functional growth models and collaboration with China

A major scientific challenge in recent years has been the development of growth models that link function with structure to improve understanding of the functioning of plants, to segregate genetic, environmental, and

technical effects, and to forecast and monitor production. Such models combine descriptions of plant architecture, local and spot ecophysiological mechanisms, and growth and ageing processes. The models depict the functional interactions between plants and their environment, which depend on the topological and geometric structure of the plant cover.

CIRAD has developed a generic growth model, known as Amappara. It is based on a description of plant architecture (eg, number, position, and length of internodes and leaves) and depicts the processes of water transfer in the plant, photosynthetic assimilation, allocation of resources to various organs, and primary and secondary growth. Depiction of these processes is regulated by environmental factors, mainly temperature, and availability of water and light. This theoretical model led to innovative experiments on cotton plants, such as systematic pruning of the plant and partial removal of leaves. The qualitative performance of the model and calculation of the parameter values could thus be tested through the experiments, conducted in collaboration with the Cotton Programme of CIRAD-CA. A similar approach is being followed for the coffee plant, in collaboration with the Coffee Programme of CIRAD-CP.

The project lies at the interface of life sciences and engineering sciences as the design, simulation, and calibration of the model require advanced mathematical and computation methods. The project was started in Montpellier and is pursued since September 1998 in China, through a partnership with the French institute for research in information technology and automation INRIA, the institute for automation of the Academy of Sciences of China, and the University of Agriculture of Beijing.

plant protection

mycopesticides to control the Mato Grosso locust

From 1992 to 1996, CIRAD and EMBRAPA, the Brazilian institute for agricultural research, conducted a study on the biology and ecology of the Mato Grosso locust (*Rhammatocerus schistocercoides* Rehn). The study highlighted the advantage of using biopesticides, particularly mycopesticides, to control the pest. The follow-up project aimed at determining the conditions for implementing this crop protection strategy.

The first step, which had already been undertaken by EMBRAPA several years ago, was to develop a mycopesticide from the spores of a local strain of the fungus *Metarhizium flavoviride*. CIRAD focused on the development of an application strategy based on the ecological and behavioural characteristics of the locust; it also designed the field experiments for mycopesticide application.

Trials to examine the effectiveness of the mycopesticide were started in 1998. They were located in the reproduction biotopes of the locust in Chapada dos Parecis in central Brazil, an area of almost regular locust outbreaks. Ultra low-volume battery-powered sprayers were used for the treatments on groups of young larvae. No other

treatments were applied, and the larvae grew in strictly natural conditions. Subsequent counts of larvae demonstrated the effectiveness of the mycopesticide as it reduced the locust population substantially within 12 days.

The technique should make locust control more cost-effective, efficient, and ecological. As a preventive control measure, the mycopesticide can be applied on larval populations in limited uncultivated areas. The method developed for *R. schistocercoides* could also be used against other economically important locust species in South America.

In the next stage of experiments, a minimum nonlethal dose (1% of the normal dose) of a standard chemical insecticide will be mixed with the mycopesticide to weaken the locust and make it more vulnerable to the fungus.

diversity of pathogens and parasites of tropical crops

The ability of pathogens to evolve as a result of natural processes and human actions is linked to their genetic diversity. An understanding of the evolutionary mechanisms and genetic diversity is essential for developing integrated pest management strategies, particularly for crops of resistant varieties.

CIRAD undertook a vast research programme, in which molecular and biochemical markers were used for studying several pathogens and their pathogenic capacity.

The studies revealed or confirmed the high genetic diversity of pathogens and parasites; for example, eight genetic groups were identified for *Xanthomonas albilineans* (bacterium causing leaf scald of sugarcane). The same diversity was observed in pathogenic capacity. However, the two parameters are not clearly correlated, as seen from studies on *X. albilineans, Radopholus similis* (root nematode of banana), and *Phytophthora megakarya* (fungus causing cocoa black pod disease). For *P. megakarya,* the most virulent isolates were found in two regions—Ibule in Nigeria and western Cameroon—where the highest levels of genetic diversity were recorded and sexual reproduction of the fungus could occur. In the case of *Magnaporthe grisea* (fungus causing rice blast), individuals belonging to the same clonal strain were observed to normally have the same range of virulence.

Genetic diversity of *Mycosphaerella fijiensis* (fungus causing black sigatoka) was high in the Philippines but much lower in Cameroon, according to PCR-RFLP (polymerase chain reaction–restriction fragment length polymorphism) analyses. The situation in Cameroon is probably due to a foundation effect, which could also explain the low diversity of *R. similis* populations in this country, as shown by AFLP (amplified fragment length polymorphism) markers and isoenzymes.

In the case of *Colletotrichum kahawae* (fungus causing anthracnose in coffee), 92% of the genetic variability observed through RAPD (randomly amplified polymorphic DNA) was distributed between populations in eastern Africa and Cameroon. The difference may be due to genetic drift. In addition, the large proportion of loci with linkage disequilibrium (deviation from random distribution of alleles) indicates the exclusively clonal character of *C. kahawae.*

M. fijiensis, on the contrary, shows no evidence of significant linkage disequilibrium, which confirms the important role of gene recombination in populations of this species.

M. grisea populations, like those of *C. kahawae,* are generally composed of clones. Only four clones were identified in the Moroccan *M. grisea* populations using RAPD markers, whereas at least 16 clonal strains were detected by SCAR (sequence characterized amplified region) markers in isolates from Yunnan, China, where sexual reproduction may occur.

Significant gene flows were observed for *M. fijiensis,* an air-

borne fungus. Populations one hundred kilometres apart showed the same diversity in the Philippines; in Cameroon as well, samples taken from a banana plant and those from the plot in which it is located showed the same diversity.

These studies were undertaken in collaboration with several national and regional research institutes: CRBP and IRAD, Cameroon; CRF, Kenya; INRA, Morocco; CATIE, Costa Rica; CRU, Trinidad and Tobago; CNRRI, China; CIFC, Portugal; CABI, United Kingdom; and INRA and IRD, France.

The studies showed that the pathosystems sometimes exhibited significant genetic diversity, which can indicate a potential for evolution. Further studies are required of the reproductive (clonal or sexual) and epidemiological (weak or strong potential of dissemination) characteristics of the organisms. CIRAD and its partners have launched a new research programme on the effects of plant resistance on the dynamics and genetic structure of pathogen populations. This is a crucial issue for sustainable management of plant resistance to pathogens with a high evolution potential.

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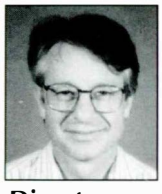

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Director, Montpellier Research Centre
Gérard Matheron

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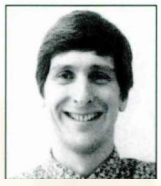
CIRAD-CA
Alain Capillon



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CIRAD-EMVT
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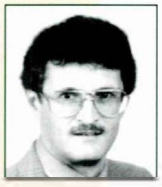

CIRAD-Fôret
Jacques Valeix

CIRAD-TERA
Jean Pichot

CIRAD-AMIS
Vincent Dollé

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Human Resources
François Fort, Manager

Installations and Maintenance
Didier Servat, Manager

French Overseas Departments and Territories
François Pointereau, Head

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(see page 95)

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Deputy Director
Jacques Meunier

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Plant improvement
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Crop protection
Marie-Line Caruana

Animal production
Philippe Lhoste

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(appointment pending)

Economics and sociology
(appointment pending)

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André Martin

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André de Courville

Asia, South Pacific
Jean-Luc Renard

International organizations, Middle East
Pierre-Luc Puglièse

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(see page 95)

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Partnerships, funding and development organizations
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Event management
Anne Hébert

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Benoît Catrisse

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Head, Horticultural Products Programme (appointment pending)

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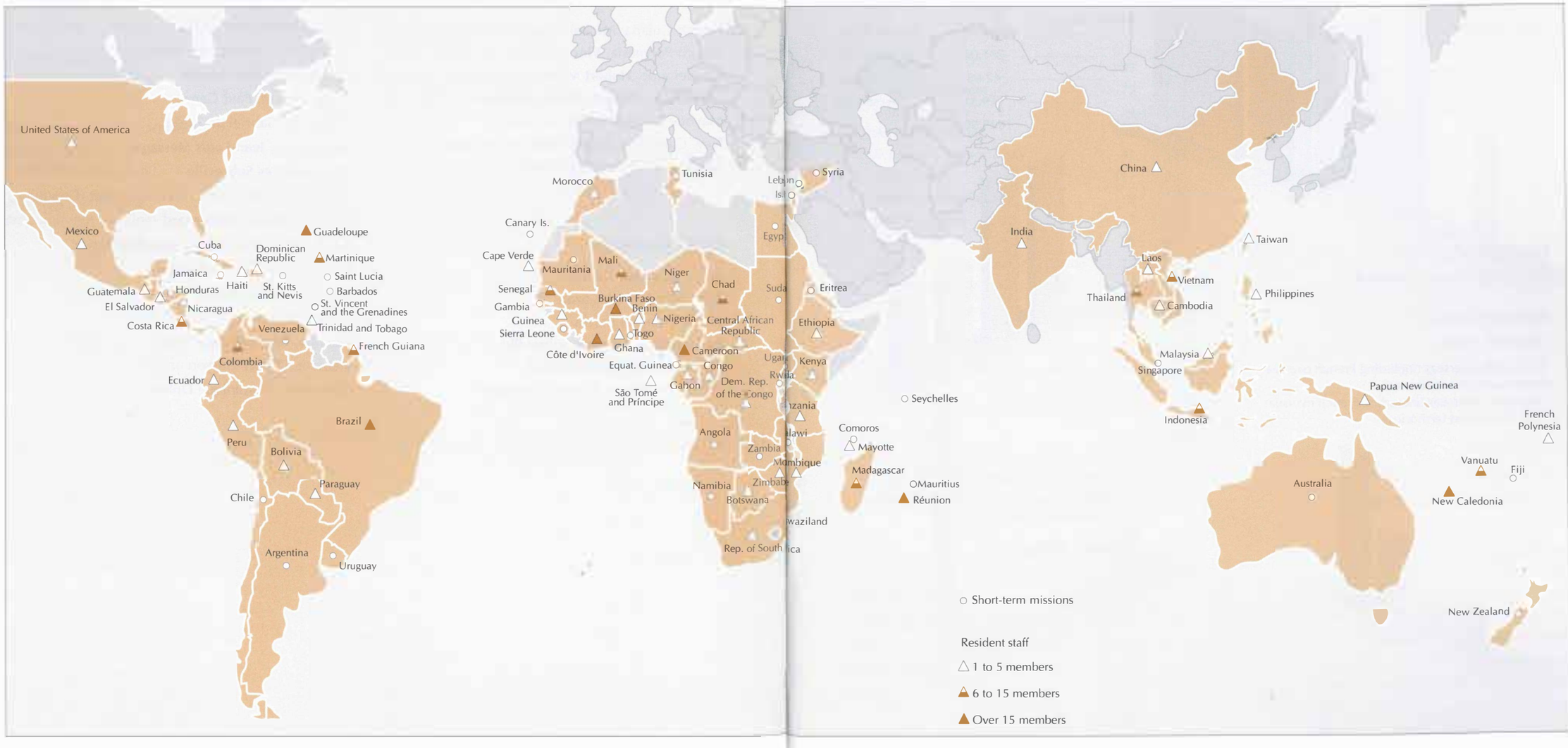
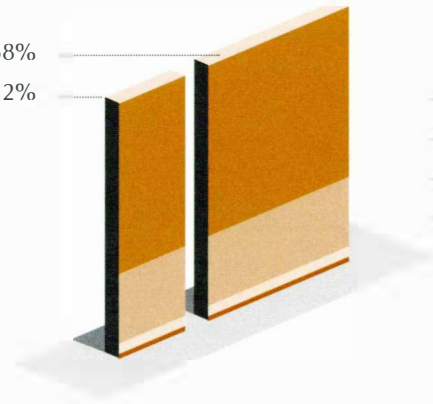


Budget and Personnel in 1998

Income and expenditure

Income	
BCRD* subsidy	68%
Other income	32%

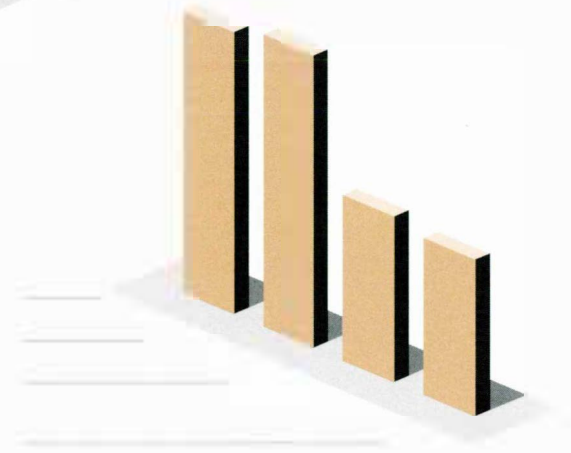
* Civil research and development budget

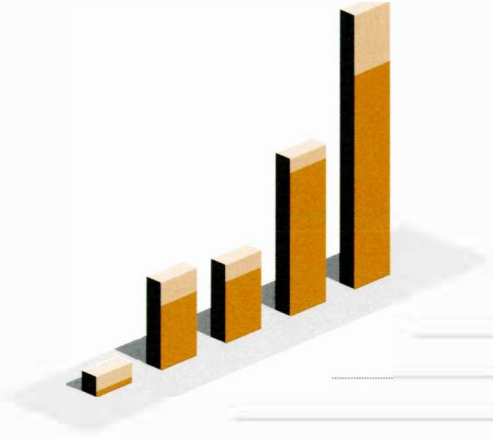


Expenditure (FFr million)	
687.50	Personnel exp.
281.01	Operating exp.
42.08	Other expenses
19.31	Investments
1029.90	

Distribution of staff by category and location

Senior staff, France,	568
Other staff, France	589
Senior staff, overseas (including French overseas departments and territories)	334
Other staff, overseas (including French overseas departments and territories)	316
	1807





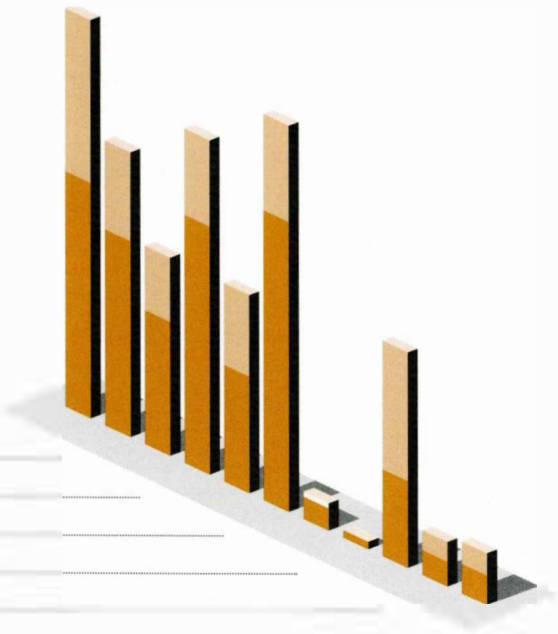
Geographic distribution of senior staff overseas (including French overseas departments and territories)

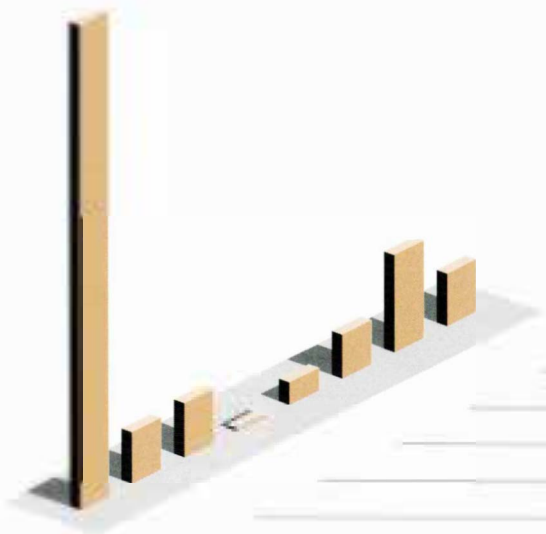
Missions (researcher year)	**Postings**	
40.9	**146**	Africa, Indian Ocean
9.3	**98**	French overseas depart. and terr.
11.4	**42**	Latin America
15.7	**44**	Asia, Oceania
9.8	**4**	Others
87.1	**334**	

Training in 1998

Distribution by discipline and type of training

	Degree courses	Professional training
Agronomy	**95**	66
Plant improvement	**79**	36
Crop protection	**54**	26
Animal production	**100**	35
Economics and sociology	**47**	33
Technology	**117**	39
Applied mathematics	**9**	2
Remote sensing	**3**	
Informatics	**35**	52
Scientific and technical information	**10**	8
Administration and management	**12**	9
	561	**306**





Distribution of trainees by geographic origin

56	Northern Africa
104	Western Africa
47	Central Africa
24	Eastern Africa
3	Southern Africa, Indian Ocean region
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867	

CIRAD Addresses

Headquarters

42, rue Scheffer
75116 Paris
France
Telephone: +33 (0)1 53 70 20 00
Fax: +33 (0)1 47 55 15 30

Montpellier Research Centre

BP 5035
34032 Montpellier Cedex 1
France
Telephone: +33 (0)4 67 61 58 00
Fax: +33 (0)4 67 61 59 86

International Campus, Jardin Tropical

45 bis, avenue de la Belle-Gabrielle
94736 Nogent-sur-Marne Cedex
France
Telephone: +33 (0)1 43 94 72 00
Fax: +33 (0)1 43 94 73 49

CIRAD in the French overseas departments and territories

French Guiana
BP 701
97387 Kourou Cedex
Telephone: +33 (0)5 94 32 73 50
Fax: +33 (0)5 94 32 73 51

French Polynesia
BP 467
98713 Papeete
Telephone: +689 42 47 03
Fax: +689 42 46 93

Guadeloupe
Station de Neufchâteau
Sainte-Marie
97130 Capesterre-Belle-Eau
Telephone: +33 (0)5 90 86 30 21
Fax: +33 (0)5 90 86 80 77

Martinique
BP 153
97202 Fort-de-France Cedex
Telephone: +33 (0)5 96 71 92 01
Fax: +33 (0)5 96 63 07 24

Mayotte
BP 1304
97600 Mamoudzou
Telephone: +33 (0)2 69 61 21 21
Fax: +33 (0)2 69 61 21 19

New Caledonia
BP 73
98890 Païta
Telephone: +687 35 36 84
Fax: +687 35 32 55

Réunion
BP 20
97408 Saint-Denis Messageries
Cedex 9
Telephone: +33 (0)2 62 52 80 00
Fax: +33 (0)2 62 52 80 01

CIRAD in other countries

Benin
CIRAD–IITA
08 BP 0932
Cotonou
Telephone: +229 35 01 88
Fax: +229 35 05 56

Botswana
c/o SACCAR
Private Bag 00108
Gaborone
Telephone: +267 328 775
Fax: +267 328 806

Brazil
SHIS–QI 15
Conjunto 3, casa 1
71 635-230 Brasilia DF
Telephone: +55 61 248 20 79 or 56 65
Fax: +55 61 248 26 19

Burkina Faso
01 BP 596
Ouagadougou 01
Telephone: +226 30 70 70
Fax: +226 30 76 17

Cameroon
BP 2572
Yaoundé
Telephone: +237 21 25 41
Fax: +237 20 29 69

Caribbean islands
Station de Neufchâteau
Sainte-Marie
97130 Capesterre-Belle-Eau
Guadeloupe, France
Telephone: +33 (0)5 90 86 30 21
Fax: +33 (0)5 90 86 80 77

Central America
c/o IICA/PROMECAFE
Apartado postal 6742-1000
San José
Costa Rica
Telephone: +506 556 09 38
Fax: +506 556 09 38

Colombia

Apartado aéreo 34565
Cali Valle
Telephone: +57 2 892 05 99
Fax: +57 2 892 06 22

Congo

BP 1264
Pointe-Noire
Telephone: +242 94 31 84
Fax: +242 94 47 95

Côte d'Ivoire

01 BP 6483
Abidjan 01
Telephone: +225 22 18 69
or 21 16 25
Fax: +225 21 43 68

Gabon

BP 643
Libreville

Guinea

c/o MCAC
Ambassade de France
BP 570
Conakry
Telephone: +224 45 58 06
Fax: +224 45 58 06

Indian Ocean region

BP 20
97408 Saint-Denis Messageries
Cedex 9
Réunion, France
Telephone: +33 (0)2 62 52 80 00
Fax: +33 (0)2 62 52 80 01

Indonesia

Plaza Bisnis Kemang Lt. 3
Jalan Kemang Raya No. 2
Jakarta Selatan 12730
Telephone: +62 21 719 90 67
Fax: +62 21 7179 33 04

Madagascar

BP 853
Antananarivo
Telephone: +261 20 22 271 82
Fax: +261 20 22 209 99

Mali

BP 1813
Bamako
Telephone: +223 21 42 93 or 77 01 50
Fax: +223 21 87 17

Senegal

37, avenue Jean XXIII
BP 6189
Dakar-Etoile
Telephone: +221 822 44 84
Fax: +221 821 18 79

South Africa, Republic of

Agribis c.c.
PO Box 70793
Bryanston 2021
Telephone: +27 11 706 77 83
Fax: +27 11 706 76 54

South Pacific

BP 73
98890 Païta
New Caledonia
Telephone: +687 35 36 84
Fax: +687 35 32 55

Thailand

c/o Kasetsart University
Jubilee Building, 9th floor
Paholyothin Road
Bangkhen
Bangkok 10900
Telephone: +66 2 942 86 84
Fax: +66 2 942 86 83

United States

Development Research Associates
8313 Woodhaven Blvd.
Bethesda
Maryland 20817
Telephone: +1 301 365 6855
Fax: +1 301 365 6855

Vanuatu

BP 231
Santo
Telephone: +678 36 320
Fax: +678 36 355

Vietnam

SAM Project
Vien Khoa Hoc Ky Thuat Nong Nghiep
Viet Nam - Van Dien Thanh Tri -
Hanoï
Telephone: +84 48 61 59 70
Fax: +84 47 18 49 67

Zimbabwe

Fauna Project
PO Box 1378
Harare
Telephone: +263 4 702 766
Fax: +263 4 722 850

Website: www.cirad.fr
(See ADRESSES, PLANS, ANNUAIRE on the homepage for e-mail addresses.)

List of Acronyms

AFD, Agence française de développement, France

AFDI, Agriculteurs français et développement international, France

ANVAR, Agence nationale de la valorisation de la recherche, France

APROFA, Agence pour la promotion des filières agricoles, Mali

ARC, Agricultural Research Council, Rep. of South Africa

ARCOTRASS, Arnold Consulting and Trading Association GmbH, Germany

ARDRI, Agricultural and Rural Development Research Institute, Rep. of South Africa

ASARECA, Association for Strengthening Agricultural Research in Eastern and Central Africa, Uganda

BDPA, Bureau pour le développement de la production agricole, France

BUROTROP, Bureau for the Development of Research on Tropical Perennial Oil Crops, France

CABI, Commonwealth Agricultural Bureau International, UK

CATIE, Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

CERNA, Centre régional de nutrition et d'alimentation appliquée, Benin

CERNA, Centre d'économie industrielle, Ecole nationale supérieure des mines de Paris, France

CFDT, Compagnie française pour le développement des fibres textiles, France

CGIAR, Consultative Group on International Agricultural Research, USA

CIAT, Centro Internacional de Agricultura Tropical / International Center for Tropical Agriculture, Colombia

CIFOR, Centre for International Forestry Research, Indonesia

CIMMYT, Centro Internacional de Mejoramiento de Maíz y Trigo / International Maize and Wheat Improvement Center, Mexico

CIRDES, Centre international de recherche-développement sur l'élevage en zone subhumide, Burkina Faso

CIRES, Centre ivoirien de recherche économique et sociale, Côte d'Ivoire

CNEARC, Centre national d'études agronomiques des régions chaudes, France

CNEVA, Centre national d'études vétérinaires et alimentaires, France

CNRADA, Centre national de recherche agronomique et de développement agricole, Mauritania

CNRRI, China National Rice Research Institute, China

CNRS, Centre national de la recherche scientifique, France

CNRST, Centre national de la recherche scientifique et technologique, Burkina Faso

COGENT, Coconut Genetic Resources Network, Singapore

CONICIT, Consejo Nacional de Investigaciones Científicas y Tecnológicas, Venezuela

CORAF, Conférence des responsables de recherche agronomique en Afrique de l'Ouest et du Centre, Senegal

CRBP, Centre de recherches régionales sur bananiers et plantains, Cameroon

CRF, Coffee Research Foundation, Kenya

CRU, Cocoa Research Unit, Trinidad and Tobago

CTA, Centre technique de coopération agricole et rurale (ACP–UE) / Technical Centre for Agricultural and Rural Cooperation (ACP–UE), The Netherlands

CTBA, Centre technique du bois et de l'ameublement, France

DDRP, Direction du développement rural et de la pêche, New Caledonia

DIARF, Direction des inventaires, des aménagements et de la régénération des forêts, Congo

EGFAR, Electronic Global Forum for Agricultural Research

EIARD, European Initiative for Agricultural Research for Development

EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil

ENDA-GRAF, Environnement et développement du tiers-monde, groupe recherche, action, formation, Senegal

ENEF, Ecole nationale des eaux et forêts, Congo

ENGREF, Ecole nationale du génie rural, des eaux et des forêts, France

ENSAM, Ecole nationale supérieure des arts et métiers, France

ENSAM, Ecole nationale supérieure agronomique de Montpellier, France

ENSIA, Ecole nationale supérieure des industries alimentaires, France

ENV, Ecole nationale vétérinaire, France

ESIMAQ, Ecole supérieure de management de la qualité, Morocco

FAO, Food and Agriculture Organization of the United Nations, Italy

FOFIFA, Foibe Fikarohana Ampiharina amin-ny Fampandrosoana ny Ambanivohitra, Madagascar

GAPKINDO, Gabungan Produsen Karet Indonesia, Indonesia

GEVES, Groupement d'étude des variétés et des semences, France

GTZ, Deutsche Gesellschaft für Technische Zusammenarbeit, Germany

IAC, International Agricultural Centre, The Netherlands

IAM, Institut agronomique méditerranéen, France

IBSRAM, International Board for Soil Research and Management, Thailand

ICAC, International Cotton Advisory Committee, USA

ICRAF, International Centre for Agroforestry, Indonesia

ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India

IER, Institut d'économie rurale, Mali

IGN, Institut géographique national, France

IICT, Instituto de Investigação Científica Tropical, Portugal

ILRI, International Livestock Research Institute, Ethiopia, Kenya

INA-PG, Institut national agronomique Paris-Grignon, France

INC, Institut national de la cartographie, Gabon

INERA, Institut de l'environnement et des recherches agricoles, Burkina Faso

INGENIC, International Group for Genetic Improvement of Cocoa, UK

INIAP, Instituto Nacional de Investigaciones Agropecuarias, Ecuador

INIBAP, International Network for the Improvement of Banana and Plantain, France

INIFAP, Instituto Nacional de Investigaciones Forestales y Agropecuarias, Mexico

INRA, Institut national de la recherche agronomique, France

INRA, Institut national de la recherche agronomique, Morocco

INRAN, Institut national de recherches agronomiques du Niger, Niger

INRIA, Institut de recherche en informatique et en automatique, France

IPGRI, International Plant Genetic Resources Institute, Italy

IRAD, Institut de recherche agricole pour le développement, Cameroon

IRD, Institut de recherche pour le développement (formerly ORSTOM), France

IRIE, Fondation pour l'innovation et la recherche industrielle en Europe, France

IRRI, International Rice Research Institute, Philippines

ISRA, Institut sénégalais de recherches agricoles, Senegal

ISSCT, International Society of Sugarcane Technologists, Mauritius

ITA, Institut de technologie alimentaire, Senegal

ITCF, Institut technique des céréales et des fourrages, France

KIT, Koninklijk Instituut voor de Tropen, The Netherlands

LARES, Laboratoire d'analyse régionale et d'expertise sociale, Benin

LRVZ, Laboratoire de recherches vétérinaires et zootechniques, Chad

LSTM, Laboratoire des symbioses tropicales et méditerranéennes, France

NAFTA, North American Free Trade Agreement

NCDP, National Coconut Development Programme, Tanzania

NRI, Natural Resources Institute, UK

ODEADOM, Office de développement de l'économie agricole des départements d'outre-mer, France

OIE, Office international des épizooties, France

OPM, Oxford Policy Management, UK

PARC, Pan African Rinderpest Campaign

PCA, Philippine Coconut Authority, Philippines

PORIM, Palm Oil Research Institute of Malaysia, Malaysia

PRASAC, Pôle régional de recherche pour les savannes d'Afrique centrale

PRIAG, Programa Regional de Reforzamiento a la Investigación Agronómica sobre los Granos en Centroamérica, Costa Rica

RECA, Réseau de recherche caféière en Afrique, Côte d'Ivoire

SACCAR, Southern African Centre for Cooperation in Agricultural Research, Botswana

SAED, Société nationale d'aménagement et d'exploitation des terres du delta du fleuve Sénégal et de la Falémé, Senegal

SIA, Salon International d'Agriculture, France

SNGF, Silo nationale des graines forestières, Madagascar

SPC, Secretariat of the Pacific Community (formerly South Pacific Commission), New Caledonia

URDOC, Unité de recherche-développement observatoire du changement, Mali

UR2PI Unité de recherches pour la productivité des plantations industrielles, Congo

USDA, United States Department of Agriculture, USA

VARTC, Vanuatu Agricultural Research and Training Centre, Vanuatu

VTT, Valtion Teknillinen Tutkimuskeskus, Finland

WARDA, West Africa Rice Development Association, Côte d'Ivoire

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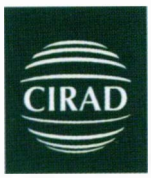

**Centre
de coopération
internationale
en recherche
agronomique
pour le
développement**

42, rue Scheffer
75116 Paris
France